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PROTECTION OF DOMESTIC WATER SUPPLIES AND STUDIES OF POLLUTIONAL PARAMETERS DURING THE GREEN RIVER FISH CONTROL PROJECT

PUBLIC HEALTH SERVICE, DENVER, COLORADO

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During September, 1962, a large-scale fish control project was initiated on the upper Green River in order to eliminate rough fish populations prior to the closure of Flaming Gorge Dam, which would form a 90-mile-long reservoir. The toxicant operation was successful in eliminating the fish, and activated carbon removed toxicity, taste, and odor from the treated river water to a satisfactory degree for domestic use.

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U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of State Services
Division of Water Supply and Pollution Control
Region VIII
Denver, Colorado

Colorado River Basin Water Quality Control Project

July 1963

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Stauffer Chemical Company, Green River, Wyoming

Intermountain Chemical Company, Westvaco, Wyoming

California Oil Company, Red Wash, Utah

Town of Green River, Utah

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PROTECTION OF DOMESTIC WATER SUPPLIES AND STUDIES OF POLLUTIONAL PARAMETERS DURING THE GREEN RIVER FISH CONTROL PROJECT

by

Croswell Henderson[1/]

INTRODUCTION

During September 1962, a large-scale fish control project was initiated on the upper Green River by the Wyoming and Utah Fish and Game Departments and the U. S. Fish and Wildlife Service. The purpose of the project was to eliminate rough fish populations prior to the closure of Flaming Gorge Dam, which would form a 90-mile-long reservoir. Fishery investigations by Wyoming (1) and Utah (2) had indicated that few game fish were present in the area and that rough fish populations were high. The area would later be restocked with desirable game species such as trout which would have a much better opportunity for survival and growth in the new reservoir.

Approximately 450 miles of the Green River and tributaries were treated with 21,495 gallons of an emulsifiable rotenone formulation. Below the treated area, 17,600 pounds of potassium permanganate was added to destroy the toxic effects of rotenone and to prevent fish mortality in the Dinosaur National Monument (3).

Some concern was expressed over the possible effects of the toxicant application on water uses, especially domestic water supplies. The toxicant formulation was highly odorous and 5 ppm would impart a strong "Kerosene-like"

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taste and odor to the river water. Also, large quantities of dead and decaying fish might be present in the river for several weeks following the toxicant application.

Five domestic water plants, four in Wyoming and one in Utah, obtained water from the Green River in the reach to which toxicant was applied. As no alternative water supplies and a minimum of storage capacity were available, it would be necessary to use water from the river during most of the toxicant operation. Two additional water plants in Utah, downstream from the toxicant operation, also obtained water from the Green River.

Rotenone has been used for many years as a fishery management tool for removal of rough fish populations. There are no indications that this practice has had any harmful effects on humans or other warm-blooded animals. Information of the toxicity of rotenone and some experiences regarding its use are summarized in a previous publication (4). Previous laboratory and field studies by the Public Health Service had also shown that toxicity, tastes, and odors could successfully be removed with activated carbon (4,5,6).

Colorado River Basin Project personnel were requested to participate in the toxicant operation and, in cooperation with Wyoming and Utah State Health Departments, to assist water plant operators in producing a palatable water. It was also felt that this was an opportune time to study the effects of the fish toxicant application on certain pollutional parameters. No knowledge was available as to what effects might be produced either from the toxicant or the expected large tonnage of decaying fish on such parameters as coliform count or BOD. Also, little was known concerning the effect of the toxicant on bottom macro-invertebrates which are often used as a measure of pollution.

SUMMARY AND CONCLUSIONS

1. The toxicant operation was successful in that the kill of fish in the treated area was essentially complete. Relatively few fish were killed below the detoxification station.
2. Activated carbon removed toxicity, taste, and odor from the treated river water to a satisfactory degree for domestic use. Seven water plants within and below the treated area continued operations with few consumer complaints.
3. The laboratory procedures developed for estimating toxicant concentration and amount of carbon needed proved adequate for an operation of this kind. Likewise, several different methods of adding carbon at water plants were satisfactory.
4. Expected odors from dead fish did not materialize, probably because the dead fish were well scattered throughout the river with no accumulations sufficient to produce an odor in the water.
5. Physical and chemical determinations included pH, alkalinity, hardness, conductivity, temperature, dissolved oxygen, biochemical oxygen demand, manganese, and ammonia. It may be concluded that there was no major significant effect on any of these characteristics which could be attributed to the toxicant operation. While some minor changes occurred during the study period, these changes were mostly attributable to other causes such as heavy rainfall in the area. Minor changes in pH, dissolved oxygen, and ammonia may have been caused from the toxicant or resulting effects such as dead fish and increased growth of aquatic vegetation.

6. The bacteriological data show a high coliform level below Green River, Wyoming, a condition which would be undesirable if it still exists when Flaming Gorge Dam is completed and the reservoir used for recreational purposes. There is no evidence from the studies which shows any effect of the fish toxicant or dead fish on the coliform population in the river. Higher levels at Green River, Utah, were attributed to heavy rainfall and resulting runoff. Finished water from all water treatment plants in the toxicant treated area and below was of acceptable bacterial quality.

7. Bottom animal samples collected two weeks after the toxicant application showed a drastic reduction and practically an elimination of bottom animals throughout the treated area. Six months later, little or no recovery was apparent.[1/] At this same time, a very good bottom animal population was found above the toxicant treated area and in Dinosaur National Monument, below the detoxification station.

8. Plankton samples taken before and after the toxicant operation indicated little change in phytoplankton population. Zooplankters, however, were practically eliminated except for protozoans, which greatly increased. Visual observation two weeks following the toxicant operation showed the river much clearer than before, probably because of the elimination of bottom feeding fish. A fairly heavy growth of a filamentous green algae and the stalked diatom, Gomphonema, covered the river bottom. Following the winter ice cover, this decaying vegetation caused some difficulty in the operation of the Green River, Wyoming, water plant.

1/ Additional information on recovery of bottom animals has been obtained since this report was written. See Footnote on page 59.

THE TOXICANT OPERATION (3)

Approximately 450 miles of streams were treated with a fish toxicant during the operation. The reach of the Green River treated extended for about 225 miles from above Big Piney, Wyoming, through Wyoming and Utah to 10 miles above Flaming Gorge Dam. The remainder of the mileage consisted of tributaries entering the Green River within this reach. Residual effects of the toxicant extended about 20 additional miles to the detoxification station near the Utah-Colorado border.

The toxicant used was an emulsifiable rotenone formulation, Chem-Fish Regular, containing 5 percent rotenone, a methylated napthalene solvent, and an emulsifier. Toxicant application stations were set up at 10-mile invervals on the Green River and major tributaries. Toxicant was also applied to smaller tributaries, usually at a point just above their confluence with the Green River. The location of toxicant application stations is shown in Figure 1. At main river stations the toxicant was applied through precalibrated valves on hoses stretched across the river. Enough formulation was added to maintain a concentration of 5 ppm (formulation) in the river water except at the lower three stations which was reduced to 3 or 4 ppm.

Toxicant was applied at each station for a period of seven hours. Application from each successive downsteam station started three hours after the one above had been placed in operation. The schedule for beginning the release of toxicant at main river stations is shown in Table 1. A

Reproduced from best available copy.

TABLE 1

Schedule of Toxicant Applications

Green River

Formulation released for 7 hours at each station - Stations approximately 10 miles apart - River velocity approximately 1 to 1½ mph.

Station	Start Application		Concentration	Remarks
1	Sept. 4 (Tuesday)	8:00 a.m.	5 ppm	
2		11:00 a.m.	"	
3		2:00 p.m.	"	
4		5:00 p.m.	"	
5		8:00 p.m.	"	
6		11:00 p.m.	"	
7	Sept. 5 (Wednesday)	2:00 a.m.	"	Fontenelle Camp water plant 10 mi. below this station
8		5:00 a.m.	"	Below Fontenelle water plant
9		8:00 a.m.	"	
10		11:00 a.m.	"	
11		2:00 p.m.	"	Stauffer Chemical Co. approx. 5 mi. below this station
12		5:00 p.m.	"	
13		8:00 p.m.	"	Green River, Wyoming, water plant approx. 5 mi. below this station
14		11:00 p.m.	"	
15	Sept. 6 (Thursday)	2:00 a.m.	"	
16		5:00 a.m.	"	
17		8:00 a.m.	"	
18		11:00 a.m.	4 ppm	
19		2:00 p.m.	"	
20		5:00 p.m.	"	
21		8:00 p.m.	"	
22		11:00 p.m.	3 ppm	Approx. 10 mi. above Flaming Gorge Dam - Dutch John water intake 10 mi. below this station

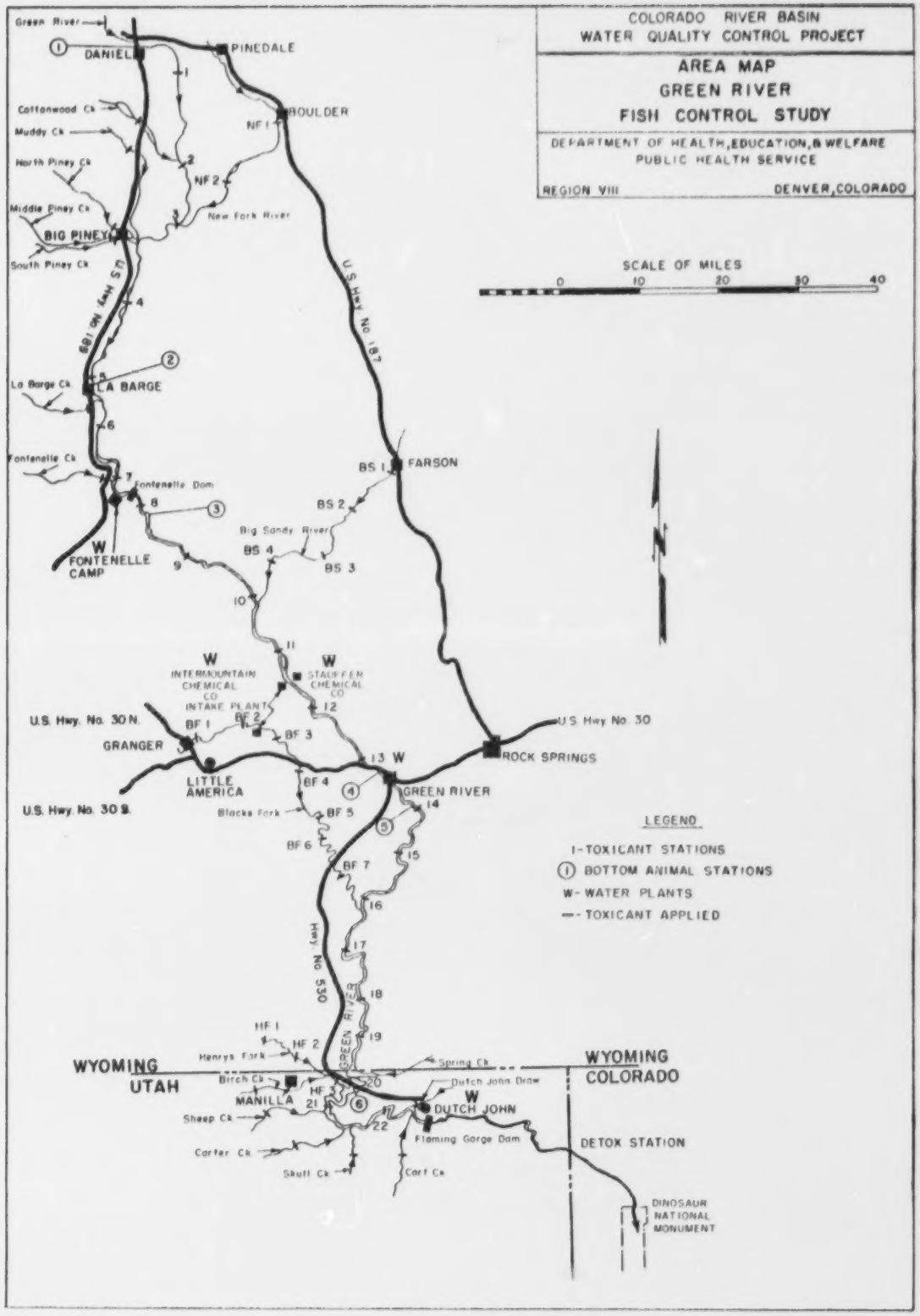
COLORADO RIVER BASIN
WATER QUALITY CONTROL PROJECT
AREA MAP
GREEN RIVER
FISH CONTROL STUDY
DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII
DENVER, COLORADO
SCALE OF MILES
0 10 20 30 40
Green River
DANIEL
PINEDALE
BOULDER
Cottonwood Ck
Muddy Ck
North Piney Ck
Middle Piney Ck
South Piney Ck
BIG PINEY
New Fork River
NF 1
NF 2
U.S. Hwy No. 187
LA BARGE
La Barge Ck
Fontenelle Ck
Fontenelle Dam
FONTENELLE CAMP
FARSON
BS 1
BS 2
BS 3
BS 4
Big Sandy River
INTERMOUNTAIN CHEMICAL CO. INTAKE PLANT
STAUFFER CHEMICAL CO
U.S. Hwy. No. 30N.
GRANGER
LITTLE AMERICA
U.S. Hwy. No. 30S.
BF 1
BF 2
BF 3
BF 4
BF 5
BF 6
BF 7
Blacks Fork
ROCK SPRINGS
U.S. Hwy No. 30
GREEN RIVER
Hwy. No. 530
GREEN RIVER
HF 1
HF 2
HF 3
Henrys Fork
Birch Ck
MANILLA
Spring Ck
Dutch John Draw
DUTCH JOHN
Sheep Ck
Carter Ck
Skull Ck
Flaming Gorge Dam
Cart Ck
WYOMING
UTAH
WYOMING
COLORADO
DETOX STATION
DINOSAUR NATIONAL MONUMENT
LEGEND
I-TOXICANT STATIONS
(I) BOTTOM ANIMAL STATIONS
W-WATER PLANTS
--TOXICANT APPLIED

FIGURE 1

lethal concentration of toxicant was thus maintained over a long stretch of river for a considerable period of time. The overlap would prevent the possible escape of any fish from the river. Sloughs, backwaters, seeps, and nearby ponds were sprayed following the main operation. Approximately 21,495 gallons of toxicant were applied over a period of about three days. Over 100 men, mostly employees of the Wyoming and Utah Fish and Game Departments, participated in the toxicant application. Flows in the Green River ranged from about 200 to 900 cfs and the river velocity averaged about 1 mile per hour during the operation.

No provision was made to collect all of the dead fish. While the Wyoming Game and Fish Commission provided cleanup crews, if needed, it was believed that the fish would be scattered sufficiently so as not to create nuisance conditions. The whole area was opened to the general public, which was permitted to collect any numbers of edible fish desired.

The last toxicant application station was approximately 10 miles above Flaming Gorge Dam. It was expected, however, that a lethal concentration of toxicant would travel much further downstream. In order to prevent destruction of fish in the Dinosaur National Monument, a detoxification station was established near the Colorado-Utah border, about 40 miles below the last toxicant station and 12 miles above the upstream park boundary. At this station a strong oxidizing agent, potassium permanganate, was used to prevent further toxic effects from the rotenone.

This crystalline material was added through grinders and spreaders located on a bridge over the river. Approximately 17,600 pounds of the chemical were added over a 3-1/2 day period.

Apparently the whole operation was successful. The kill of fish at all upriver stations was considered essentially complete. Relatively few fish were killed below the detoxification station.

CONDUCT OF THE STUDIES

Water Plants Concerned

Five water plants were located in the reach of the river to which toxicant was applied (Figure 1). While all had a small amount of storage capacity, it would be necessary to obtain water from the Green River before the toxicant dissipated. The location of these plants is shown in Figure 1 and can be described as follows: Fontenelle Camp, Wyoming, population approximately 400, operated by the U. S. Bureau of Reclamation; Stauffer Chemical Company, a soda-ash plant with 400 to 500 employees and considerable use of water for industrial purposes; Intermountain Chemical Company, also a soda-ash plant with 400 to 500 employees and considerable use of water for industrial purposes; Green River, Wyoming, population about 4,000 also furnishes water to Rock Springs, Wyoming, population about 11,000 operated by the Pacific Power and Light Company; Dutch John, Utah, population about 1,200, operated by the Arch Dam Construction Company for the U. S. Bureau of Reclamation. With the exception of Fontenelle, all of the water plants had complete treatment facilities (coagulation, sedimentation,

rapid sand filtration, and chlorination) but with no special facilities for adding activated carbon. Fontenelle obtained water from the river through an infiltration gallery but had provisions for chlorination only and about two days' storage.

Two additional water plants obtained water from the Green River considerable distances downstream from the area treated with toxicant (Figure 2). The California Oil Company obtained water through infiltration wells near the Green River, about 5 miles below Jensen, Utah, and about 85 miles below the detoxification station. Green River, Utah, population 1,000, obtained water from the river about 260 miles below the detoxification station. Both of these plants had complete treatment facilities.

Field and Laboratory Operations

Temporary laboratories were set up in the Green River, Wyoming, and Dutch John, Utah, water plants. Their major purpose was to determine the toxicant concentration in raw waters, to estimate the amounts of carbon needed to remove toxicity, tastes, and odors, and to check the finished water for palatability. Other determinations, related to the effect on pollutional parameters, such as coliforms, DO, pH, alkalinity, hardness, and conductivity were made as time permitted. The Wyoming State Health Department assisted in collecting samples from upstream water plants and in conducting some of the analyses. The Utah State Health Department collected and analyzed samples for coliforms, BOD, conductivity, and manganese from the Dutch John water plant, the Green River at Jensen, Utah, and the California Oil Company intake at Red Wash, Utah, before, during, and after the toxicant application.

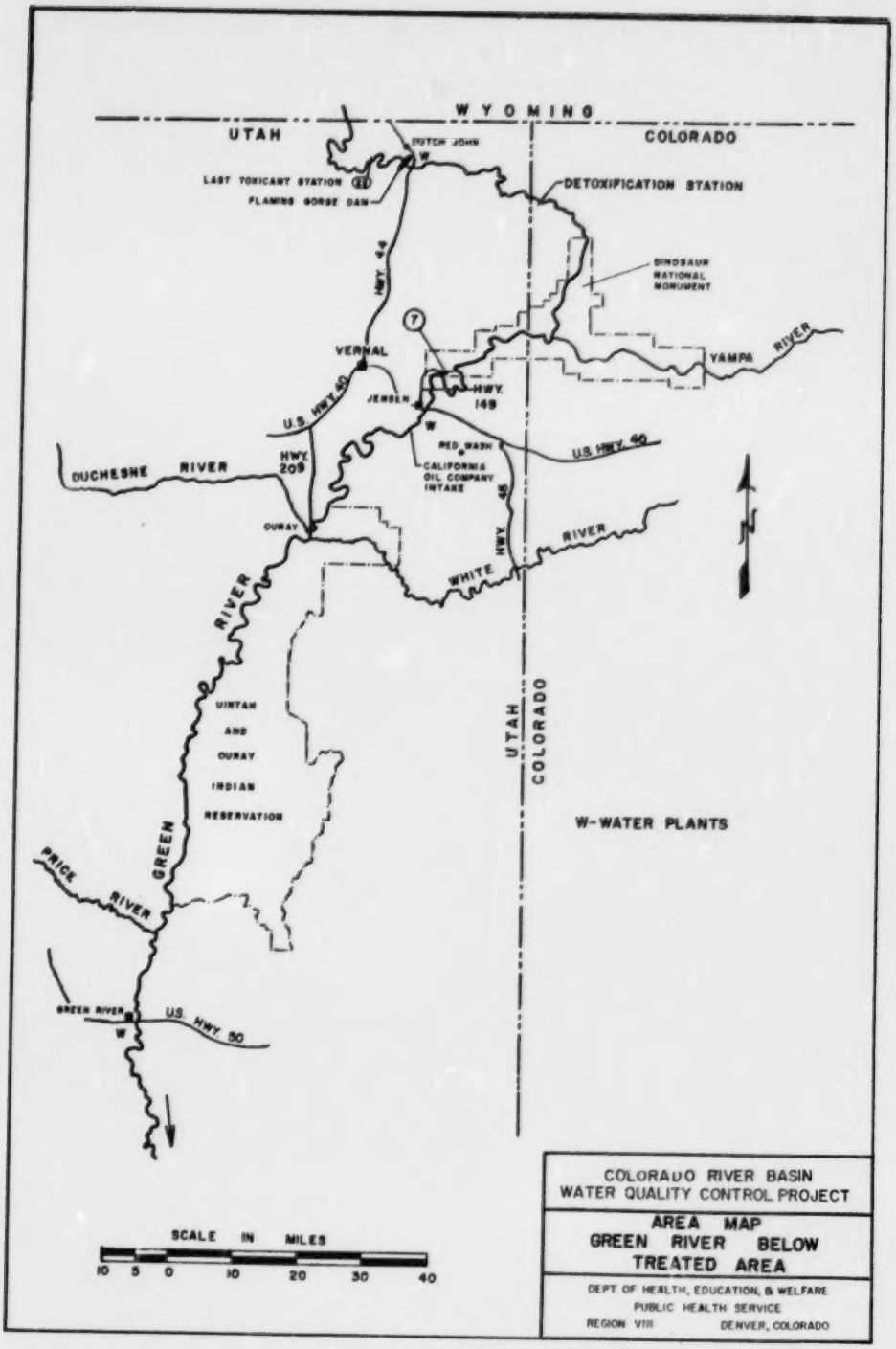
WYOMING
UTAH
COLORADO
DUTCH JOHN
LAST TOXICANT STATION
FLAMING GORGE DAM
DETOXIFICATION STATION
DINOSAUR NATIONAL MONUMENT
HWY 44
VERNAL
YAMPA RIVER
JENSEN
HWY 149
U.S. HWY 40
RED WASH
CALIFORNIA OIL COMPANY INTAKE
DUCHESNE RIVER
HWY 209
OURAY
HWY 45
WHITE RIVER
GREEN RIVER
UINTAH AND OURAY INDIAN RESERVATION
UTAH
COLORADO
PRICE RIVER
GREEN RIVER
U.S. HWY 50
W-WATER PLANTS
SCALE IN MILES
10 5 0 10 20 30 40
COLORADO RIVER BASIN
WATER QUALITY CONTROL PROJECT
AREA MAP
GREEN RIVER BELOW
TREATED AREA
DEPT OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLORADO

FIGURE 2

A mobile laboratory was set up at the Green River, Utah, water plant some 300 miles downstream from the last area of toxicant application and 260 miles below the detoxification station. While the toxicant would definitely not be expected to reach this area, the effect of the upstream operations, especially dead fish and manganese, on water quality were unknown. Thus, analyses were made on water samples before, during, and after the expected arrival of any upstream effects. Analyses included threshold odor, pH, alkalinity, hardness, conductivity, DO, BOD, manganese, ammonia, and coliforms.

Macro-invertebrate collections were made at selected stations in the Green River within the reach to which toxicant was applied (Figure 1). Three square-foot bottom animal samples were collected in riffle areas with a Surber sampler both before and after the toxicant operation. One-gallon water samples for plankton analysis were also collected at these stations.

Methods

Toxicant Analysis:

As no satisfactory chemical method of analysis for rotenone was available, analyses for toxicant concentration were made by a previously developed bioassay technique (4, 7, 8) using live fish. A series of known concentrations of toxicant (Chem-Fish Regular) in uncontaminated Green River water was prepared. Five fish (3" rainbow trout fingerlings) were added to duplicate samples of 10 liters of each of a logarithmic series of concentrations containing 5.6, 3.2, 1.8, 1.0, 0.56, 0.32, 0.18, 0.10, 0.056,

0.032, and 0.018 ppm of toxicant. Times of loss of equilibrium and death were recorded for each fish. Median loss of equilibrium and death times (Table 2) was plotted against concentration on 3-cycle logarithmic graph paper (Figure 3). A standard curve was then obtained which could be used as long as a particular group of fish were used under the same standardized conditions. From fish reactions (loss of equilibrium or death) with reference to the standard curve, the toxicant concentration in an unknown sample could be estimated. As the time of fish reaction varied somewhat with temperature, curves were prepared at several different temperatures. The values shown in Table 3 were derived from these curves and used to estimate toxicant concentrations in unknown samples.

For most accurate results, a minimum of 10 fish should be used in each test. However, during this project, it was not feasible from the standpoint of facilities available and the number of tests desired. Also, these tests were made primarily to estimate the amount of activated carbon needed in water treatment plants for toxicity and taste and odor removal. As carbon could not be precisely controlled and tests were also conducted on finished waters, it was felt that a reasonable estimate of toxicant concentration would be adequate. Thus, unknown samples were tested on the basis of two fish added to two liters of the sample adjusted to the proper temperature, if necessary. Average loss of equilibrium time was referenced to the standard curve (Figure 3) or table (Table 3) to obtain results. On finished water samples, which contained chlorine, it was necessary to add sodium thiosulfate to destroy the toxic effects of chlorine before the bioassays were conducted. Thio was added as a 1% solution; 1 ml. per liter would counteract the effects of 1 ppm chlorine.

TABLE 2

Fish Reaction Time - Concentration Relationship

Toxicant Concentration (ppm)	Loss of Equilibrium Time in Minutes		Death Time in Minutes	
	Median	Range	Median	Range
5.6	5	5-6	14	12-15
3.2	7	6-8	16	16-18
1.8	8	8-9	18	17-19
1.0	10	9-11	21	20-25
.56	13	12-17	28	27-38
.32	17	13-19	49	40-52
.18	23	19-36	56	52-89
.10	37	28-49	105	69-144
.056	78	70-95	225	177-280
.032	80% survival - 24 hrs.			
.018	100% survival - fish slightly agitated			
.010	100% survival - no effect			
Control	100% survival - no effect			

24 hr. TLm - 0.04 ppm

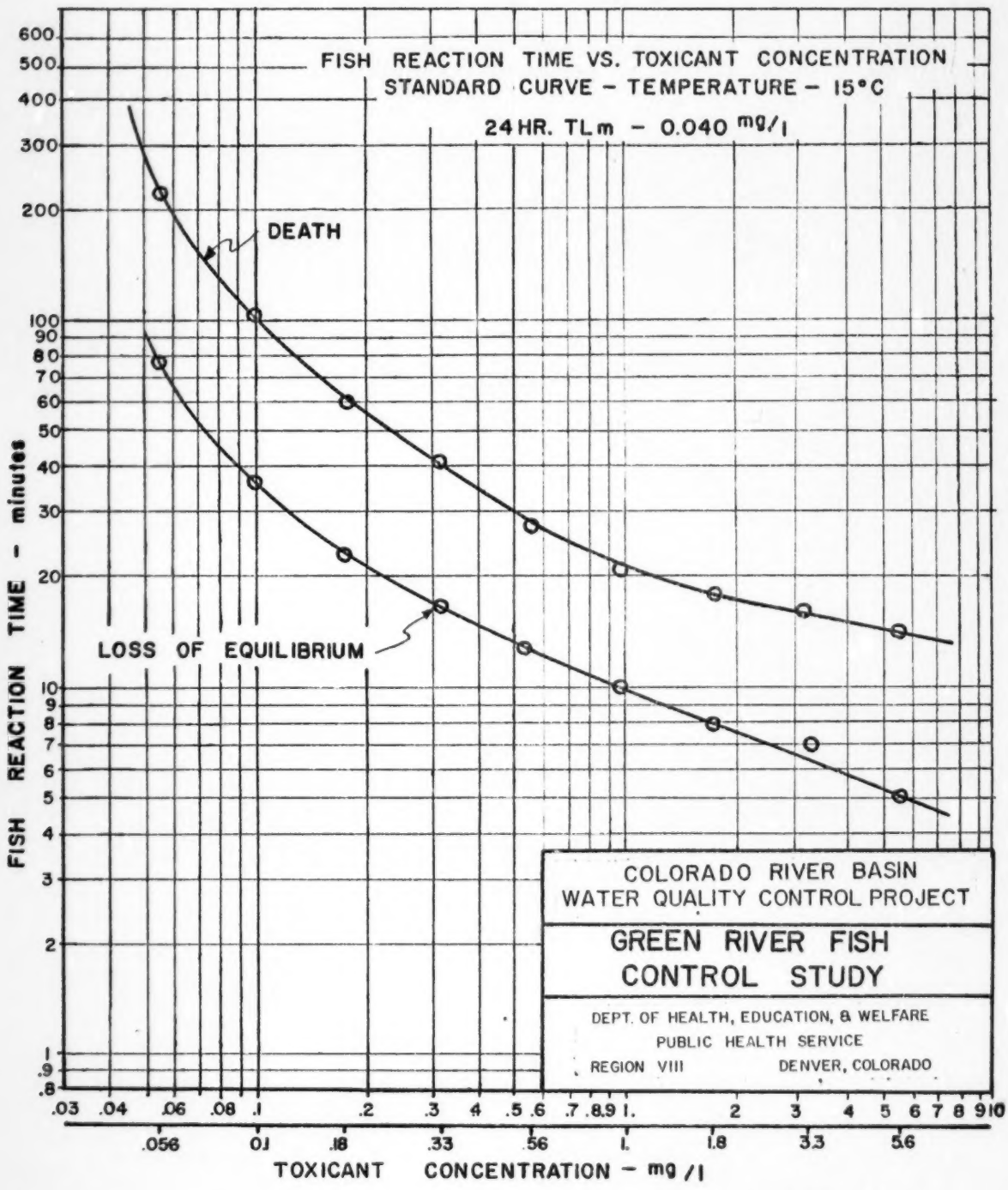
FISH REACTION TIME VS. TOXICANT CONCENTRATION
STANDARD CURVE - TEMPERATURE - 15°C
24 HR. TLm - 0.040 mg/l
DEATH
LOSS OF EQUILIBRIUM
FISH REACTION TIME - minutes
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
.9
.8
.03 .04 .06 .08 .1 .2 .3 .4 .5 .6 .7 .8 .9 1. 2 3 4 5 6 7 8 9 10
.056 .01 .18 .33 .56 1. 1.8 3.3 5.6
TOXICANT CONCENTRATION - mg/l
COLORADO RIVER BASIN
WATER QUALITY CONTROL PROJECT
GREEN RIVER FISH
CONTROL STUDY
DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLORADO

FIGURE 3

TABLE 3

Loss of Equilibrium Time - Toxicant Concentration Relationship

Median Loss of Equilibrium Time in Minutes	Concentration of Toxicant				
	15°C	16°C	17°C	18°C	19°C
5	5.6	5.6	5.6	5.6	5.6
5½	4.6	4.4	4.2	4.0	3.8
6	3.6	3.3	3.0	2.8	2.6
6½	3.0	2.7	2.4	2.1	2.0
7	2.5	2.2	1.8	1.6	1.5
7½	2.1	1.8	1.6	1.4	1.2
8	1.8	1.5	1.3	1.2	1.1
8½	1.5	1.3	1.1	1.0	0.9
9	1.3	1.1	1.0	0.9	0.8
9½	1.1	1.0	0.9	0.8	0.7
10	1.0	0.9	0.8	0.7	0.6
11	0.8	0.7	0.6	0.5	0.4
12	0.6	0.5	0.5	0.4	0.4
13	0.5	0.4	0.4	0.3	0.3
15	0.4	0.3	0.3	0.3	0.3
20	0.23	0.18	0.14	0.13	0.12
25	0.16	0.13	0.10	0.09	0.09
30	0.12	0.10	0.08	0.07	0.07
40	0.09	0.07	0.06	0.06	0.05
50	0.07	0.06	0.05	0.05	< 0.05
60	0.06	0.05	< 0.05	< 0.05	< 0.05

Threshold Odor:

A threshold odor concentration value was established for the toxicant formulation by a slight modification of the procedure given in Standard Methods (9). A series of concentrations of toxicant in odor-free water was prepared (e.g., 1, .56, .32, .18, .10, .056, .032, .018, and .010 ppm) and subjected to a panel of five members for odor determination. All panel members recorded a positive reaction down through a concentration of .032 ppm. Only one out of the five members recorded a positive reaction at .018 ppm and all recorded a negative reaction at .010 ppm. Similar experiments with Green River water gave the same results. The tests were made at room temperature of approximately 20° C. Thus, in freshly prepared emulsions, it appeared that a slightly lower concentration would produce an odor than would have an effect on fish. Additional threshold odor determinations were made on raw and finished waters by the procedure given in Standard Methods but at the actual temperature of the sample, usually 15 to 19° C. and with only two observers. The toxicant even in low concentrations produced a very strong, easily recognizable "kerosene-like" odor, no doubt from the methylated naphthalene solvent. Observers were familiar with this characteristic odor and were asked to disregard other slight odors which may be present in natural surface waters. They were, however, asked to note any objectionable fishy or decay odors which may originate from dead fish.

Estimation of Carbon Needed:

Laboratory tests were conducted to determine the amount of carbon needed to remove toxicity and odor from waters containing specific concentrations of the toxicant. Varying amounts of carbon (e.g., 150, 125, 100,

75, 50, and 25 ppm of Aqua Nuchar, powdered) were added to a series of glass bottles, each containing 10 liters of Green River water and a fixed amount of toxicant (e.g., 5 ppm). The carbon was well mixed with the water and the mixture allowed to stand for 30 minutes. Toxicity determinations indicated that 150 ppm of carbon were required to remove 5 ppm of the toxicant formulation. Threshold odor determinations also showed that odor was removed by this amount of carbon. Additional tests indicated that 60 ppm of carbon would remove both toxicity and odor from waters containing 2 ppm of toxicant. By using a straight-line arithmetic plot (Figure 4), the concentration of carbon needed to remove any concentration of toxicant could be estimated. Thus, the amount of carbon that it would be necessary to add to any water supply could be readily computed (e.g., Table 4).

Bottom Animals:

Quantitative bottom animal samples were collected at selected biological stations (Figure 1) before, two weeks after, and again six months after the toxicant application. Three square-foot composite samples were collected with a Surber sampler in shallow, rocky riffle areas. The samples were preserved with 10% formalin and later taken to the Salt Lake City laboratory for sorting, counting, and identification.

Plankton:

One-gallon water samples were collected at each biological sampling station before and two weeks after the toxicant application. The samples were preserved with 5% formalin and taken to the laboratory for counting and identification. In the laboratory, a 2-liter sample was concentrated with a Foerst centrifuge and diluted to an appropriate concentration (e.g., 20 to 80 ml.) for counting. One ml. of the concentrate was placed in a

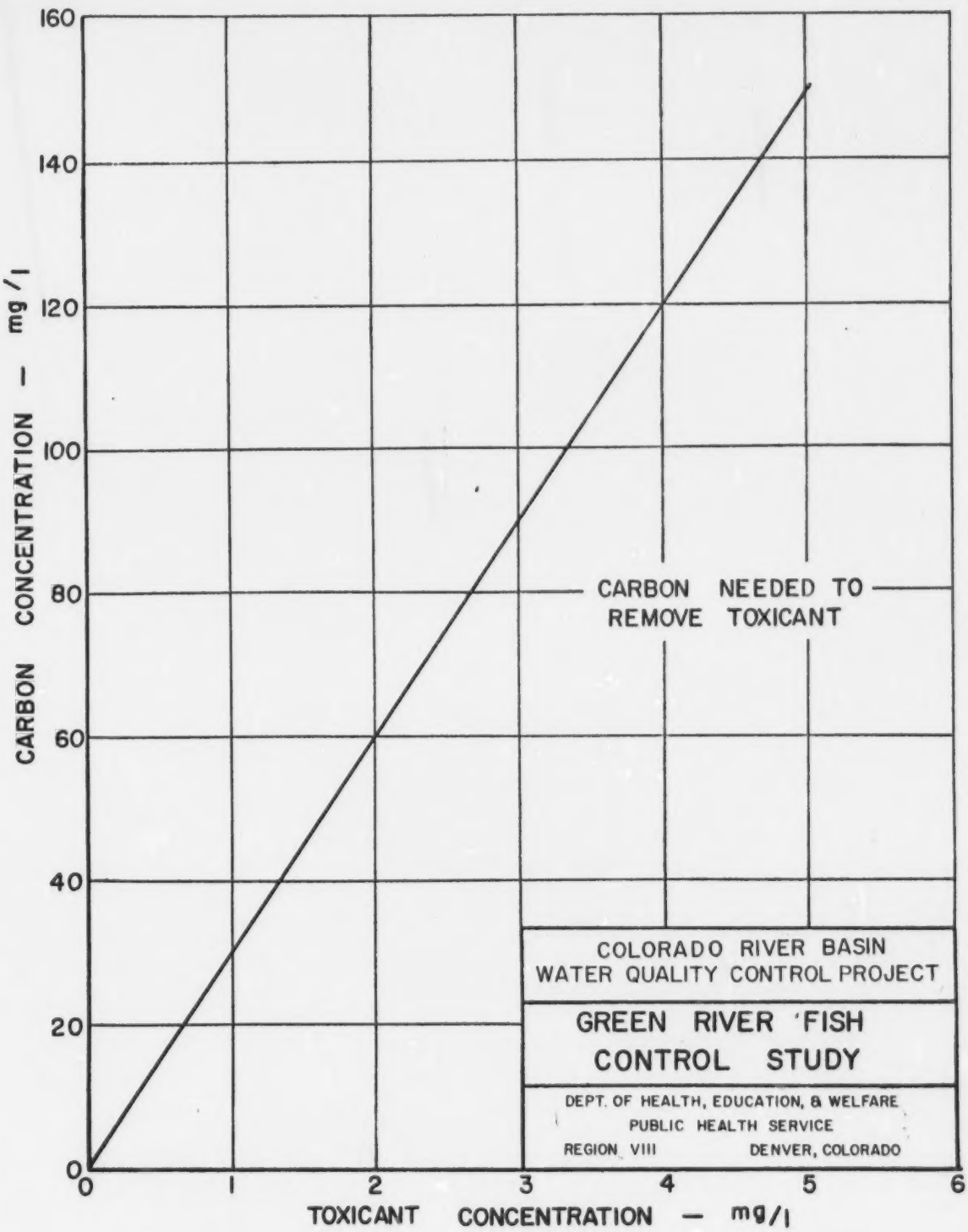
160
140
120
100
80
60
40
20
0
CARBON CONCENTRATION — mg/l
CARBON NEEDED TO REMOVE TOXICANT
0
1
2
3
4
5
6
TOXICANT CONCENTRATION — mg/l
COLORADO RIVER BASIN
WATER QUALITY CONTROL PROJECT
GREEN RIVER FISH CONTROL STUDY
DEPT. OF HEALTH, EDUCATION, & WELFARE
PUBLIC HEALTH SERVICE
REGION VIII DENVER, COLORADO

FIGURE 4

TABLE 4

Estimation of Carbon Needed

Concentration of Toxicant (ppm)	Concentration of Carbon (ppm)	Carbon Needed per Million Gallons	
		lbs. per day	lbs. per hour
5.0	150	1,250	50
4.5	135	1,125	45
4.0	120	1,000	40
3.5	105	875	35
3.0	90	750	30
2.5	75	625	25
2.0	60	500	20
1.5	45	375	15
1.0	30	250	10
0.5	15	125	5
0.1	3	25	1

Sedgwick-Rafter counting cell and one strip counted under 200X magnification. Predominant organisms were identified to genera.

Other Analyses:

Additional analyses performed on water samples within the study area included coliforms, dissolved oxygen, biochemical oxygen demand, pH, alkalinity, hardness, conductivity, manganese, and ammonia. All of these analyses were conducted according to Standard Methods (9).

PROTECTION OF WATER SUPPLIES

Periodically, during and following the toxicant operation, raw water samples from some of the water plants were analyzed for toxicant concentration by the preceding bioassay technique. Based on the analyses, the amounts of carbon needed were estimated from the prepared curve (Figure 4) and table (Table 4). The necessary amounts of carbon were added at fixed intervals to the water supply, usually through one of the chemical feeders. Samples of the finished water were assayed for toxicity and threshold odor to determine the effectiveness of the carbon treatment. Threshold odor determinations were also made on some raw water samples for comparison with toxicant analyses.

The above procedure was carried out on raw and finished water samples from some of the water plants for approximately a week or until the toxicant had naturally dissipated. Toxicant analyses were also conducted on river samples from various locations throughout the area of toxicant application and from points above and below the detoxification station. The results of toxicant and threshold odor analyses are shown in Table 5. The temperatures given are those obtained immediately on samples from raw water intakes and should represent river temperatures at these intakes. The water

TABLE 5

Results of Toxicant and Threshold Odor Analyses

Sample Location		Collected Date	Collected Time	Elapsed Time	Temp. °C	ppm Toxicant Formulation	Threshold Odor Number
Loman Ranch Bridge (5 mi. below Sta. 1)		9-4	1330	(3 hrs)		5.6	
Bridge (2 mi. above Sta. 2)		9-4	1430	(3 hrs)		5.6	
2 Miles No. of LaBarge, Wyo. (2 mi. below Sta. 5)		9-5	1530	(2 hrs)		5.6	
Names Hill (below Sta. 6)		9-7	1020	(5 hrs)		0.3	
		9-8	1120	(3 hrs)		0.07	
Fontenelle Water Intake	Raw	9-5	1200	(5 hrs)		5.6	
(just above Sta. 8)	Raw	9-6	1600	(6 hrs)		3.0	32
	Fin.					1.1	8
	Raw	9-7	1055	(5 hrs)		1.0	
	Raw	9-8	1025	(4 hrs)		0.15	
Stauffer Chemical Co.	Raw	9-6	1800	(4 hrs)		3.0	32
(5 mi. below Sta. 11)	Fin.					1.0	8
	Raw	9-7	1305	(2 hrs)		1.8	
	Raw	9-8	905	(7 hrs)		1.0	8
	Fin.					0.9	4
Big Island (Sta. 11)		9-7	1140	(4 hrs)		1.8	
Intermountain Chem.Co.	Raw	9-6	1930	(2 hrs)		3.0	32
(5 mi below Sta. 11)	Fin.					0.0	-
	Raw	9-7	900	(3 hrs)		1.8	
	Fin.					0.0	-
Green River, Wyoming,	Raw	9-5	2200		17	0.0	
Water Plant	Raw		2230		17	0.0	
(5 mi below Sta. 13)	Raw		2300		17	1.8	
	Raw		2320		17	3.0	
	Raw	9-6	800		15	2.4	32
	Raw		900		15	2.4	
	Fin.					0.0	-
	Raw		1100		16	2.4	32
	Fin.					0.0	-
	Raw		1300		17	3.0	
	Fin.					0.0	-
	Raw		1500		18	1.6	32
	Fin.					0.1	2

TABLE 5
(Continued)

Sample Location		Collected Date	Collected Time	Elapsed Time	Temp. °C	ppm Toxicant Formulation	Threshold Odor Number
Green River, Wyoming, Water Plant (5 mi. below Sta. 13) (Continued)	--Raw	9-6	1700		19	2.6	
	Fin.					.05	1
	Raw		1930		19	1.5	32
	Fin.					0.0	-
	Raw		2200		18	1.8	
	Fin.					0.0	-
	Raw		2300		17	2.3	
	Fin.					0.0	-
	Raw	9-7	830		17	2.3	32
	Fin.					0.0	-
	Raw		1000		17	1.5	
	Fin.					0.0	-
	Raw		1130		17	1.8	
	Fin.					0.0	-
	Raw		1350		17	1.8	16
	Fin.					0.0	-
	Raw		1440		17	2.3	
	Fin.					0.0	-
	Raw		1630		17	1.5	
	Fin.					0.0	-
	Raw		2115		18	1.6	8
	Fin.					.05	1
	Raw		2220		18	2.1	
	Fin.					0.0	-
	Raw	9-8	815		15	1.2	8
	Fin.					0.0	-
	Raw		1000		15	1.9	
	Fin.					0.0	-
	Raw		1200		15	1.2	
	Fin.					0.0	-
	Raw		1400		16	1.7	
	Fin.					0.0	-
	Raw		1600		16	1.1	
	Fin.					0.0	-
	Raw		1800		17	1.0	
	Fin.					0.0	-
	Raw		2115		16	1.0	8
	Fin.					0.7	4

TABLE 5
(Continued)

Sample Location		Collected Date	Collected Time	Elapsed Time	Temp. °C	ppm Toxicant Formulation	Threshold Odor Number
Green River, Wyoming, Water Plant (5 mi. below Sta. 13) (Continued)	--Raw	9-9	515		15	0.9	8
	Fin.					0.0	-
	Raw		745		15	0.9	
	Fin.					0.0	-
	Raw		945		15	0.4	4
	Fin.					0.0	-
	Raw		1240			0.5	
	Fin.					0.0	
	Raw		645			0.5	
	Fin.					0.0	
	Raw	9-10	100			0.3	
	Fin.					0.0	
	Raw		415			0.2	
	Fin.					0.0	
	Raw		1125			0.2	
	Fin.					0.0	
	Raw		1955			0.2	
	Fin.					0.0	
	Raw	9-11	130			0.1	
	Fin.					0.0	
	Raw		1110			0.1	
	Fin.					0.0	
	Raw		1930			0.0	
Hwy. No. 530 Bridge (6 mi. below Sta. 13)		9-6	1630	(5 hrs)		3.0	
		9-7	1535			3.0	
Station 18		9-6	1300	(24 hrs)		3.0	
Linwood Bridge (below Sta. 20)		9-8	1015			2.1	
			1615			1.5	
			1830			1.7	
Station 21		9-7	1045	(13 hrs)		2.3	
Station 22		9-7	1130	(12 hrs)		4.2	
Sheep Creek near Mouth		9-7	1015	(13 hrs)		0.6	

TABLE 5
(Continued)

Sample Location		Collected Date	Collected Time	Elapsed Time	Temp. °C	ppm Toxicant Formulation	Threshold Odor Number
Below Flaming Gorge Dam		9-7	1400			5.6	32
(Dutch John Water Intake)			1700			5.6	64
			2000			5.6	32
			2300			5.6	32
		9-8	800			2.1	16
			1030		16	1.7	
			1200		17	2.1	
			1500		17	2.3	
			1800		17	1.8	16
			2200		15	1.4	
		9-9	800		13	1.2	8
			1000		15	1.9	
			1100		16	1.5	
		9-10	930		15	1.2	
			1530		17	0.7	
			2100		16	0.8	
		9-11	800		15	0.5	4
Dutch John, Utah, Water--Treatment Plant (Raw water from storage pond)	Raw	9-8	1500			0.5	
	Fin.					0.0	-
	Raw		1800			0.5	4
	Fin.					0.0	-
	Raw		2200			0.9	
	Fin.					0.0	-
	Fin.	9-9	900			0.0	-
	Raw		1130			1.0	
	Raw		1300			1.1	
	Fin.					0.0	-
	Raw		1700			0.9	4
	Fin.					0.0	-
	Raw		2100			0.8	
	Fin.					0.0	-
	Raw	9-10	900			0.5	8
	Fin.					0.0	-
	Raw		1300			0.7	
	Fin.					0.0	-
	Raw		1700			0.8	4
	Fin.					0.0	1
	Raw		2100			0.5	
	Fin.					0.0	-
	Raw	9-11	800			0.5	
	Fin.					0.0	-

TABLE 5
(Continued)

Sample Location	Collected Date	Collected Time	Elapsed Time	Temp. °C	ppm Toxicant Formulation	Threshold Odor Number
Above Detox Station	9-8	740	(13 hrs)		0.14	
		1130	(9 hrs)		1.3	
		1400	(6 hrs)		1.1	
		1800	(21 hrs)		1.2	8
		2230	(17 hrs)		1.8	
	9-9	130	(13 hrs)		1.7	8
		1130	(3 hrs)		1.6	
		1530	(25 hrs)		1.2	
		2030	(21 hrs)		1.0	
		2330	(17 hrs)		0.7	
	9-10	1300	(3 hrs)		1.2	8
1/2 Mile below Detox Station	9-8	1245	(8 hrs)		0.4	4
		1800	(22 hrs)		0.0	
		2200	(18 hrs)		0.0	
	9-9	100	(13 hrs)		0.0	
		1000	(30 hrs)		0.0	
		1545	(25 hrs)		0.0	
	9-10	1345	(2 hrs)		0.0	
3 Miles below Detox Station	9-8	930	(12 hrs)		0.0	
		1430	(7 hrs)		0.09	

( ) Elapsed time between collection and analysis.

\- No odor detected.

temperatures of the other samples were not recorded at the point of collection and may have changed while in transit to the laboratory. It was necessary to adjust the temperatures of a few samples to the proper range (15 - 19° C.) before analyses were made. All analyses were made at a specific temperature within this range. If more than one hour elapsed between time of collection and analysis, the elapsed time is shown in parentheses following the time of collection.

As no toxicant was expected to reach Green River, Utah, only threshold odor analyses were conducted on samples from this water plant. Threshold odor determinations were made on raw and finished water twice a day during the period September 14-22. No odor was detected which could be attributed to the toxicant formulation or to dead fish. During the last two days, the raw waters had a muddy odor, which was attributed to extremely high turbidity caused by heavy rains in the area.

From the results of toxicant and odor analyses, it appears that the solvent odor dissipates more rapidly than the rotenone toxicity. Threshold odor numbers were only from one-third to one-half of values that would be expected from an equivalent concentration of a freshly prepared emulsion. In all of the water plant samples, removal of toxicity was accompanied by complete odor removal. In the few samples in which toxicity was not completely removed, some solvent odor also remained.

Water Plant Operation

As operations were somewhat different at the various water plants, the operation of each during the toxicant application is discussed separately.

Fontenelle Camp - As this plant had no provision for adding activated carbon, it was necessary to depend on stored water as long as possible and

to chlorinate somewhat heavier than usual if it was necessary to use river water before the toxicant concentration had passed on downstream. By restricting the use of water, it was anticipated that the 50,000-gallon storage capacity would last for two days, by which time most of the toxicant would have passed the intake. The pumps to the river were stopped at 9:00 a.m., September 5, just prior to the time the toxicant was expected to arrive. It was, however, necessary to return to pumping from the river before anticipated, primarily for fire protection. Pumping was resumed at 12:00 m., September 6, until the reservoir was filled. Samples taken at 4:00 p.m. showed 3 ppm of toxicant and a threshold odor number of 32 in the raw river water. Tap water samples showed considerable reduction to a toxicant concentration of 1.1 and a threshold odor number of 8, probably the result of both dilution in the storage reservoir and heavy chlorination (2 ppm residual). Numerous complaints of a "kerosene-like" taste and odor were received from consumers. By noon the next day, the toxicant had practically disappeared from the river. The reservoir was drained and refilled and no further complaints were received. No dead fish odors materialized and there was no further difficulty in operating this plant.

Stauffer Chemical Company - While complete treatment was practiced and adequate provision for adding carbon was available, some difficulty was encountered in the water plant in producing a palatable water. Water for domestic and industrial use was not separate and an attempt was made to treat the total water supply. Mainly due to a misunderstanding and lack of communication, inadequate carbon was used during the operation.

Pumping from the river was stopped at 6:00 p.m., September 5, and water was used from storage for 14 hours or until 8:00 a.m., September 6. Carbon was added, but in inadequate quantities for the next four days.

Only 250 pounds of carbon were used to treat approximately 1-1/2 million gallons of water. Toxicant analysis at 6:00 p.m., September 6, showed 3.0 ppm in the raw water and 1.0 ppm in the finished water. The finished water also had a fairly strong kerosene odor. On the basis of the above analysis, over 1,000 pounds of carbon would have been necessary for complete toxicant removal. There were numerous employee complaints of a kerosene taste and odor in the water. Most of them, however, said that they just didn't drink it.

Intermountain Chemical Company - Complete water treatment and adequate provision for adding carbon were available at this plant. No difficulty was encountered in producing a palatable water during the toxicant operation. The river intake for this plant was immediately across the river from Stauffer and the water was pumped about 10 miles to the plant. About 80,000 gallons per day were used for domestic purposes and about 1,000,000 per day for industrial purposes. The domestic water was adequately treated with carbon for about six days following the toxicant application.

Pumping from the river was stopped at 6:00 p.m., September 5, and water was used from storage for 24 hours. Carbon was added at the rate of 150 ppm for the following 2 days and at 60 ppm for an additional 4 days. The total amount of carbon used was estimated at 400 to 500 pounds. Analyses on raw water samples showed a maximum concentration of 3 ppm of toxicant. Finished water samples showed no toxicity and no odor. No employee complaints were received.

Green River, Wyoming - Complete water treatment was available at this plant including coagulation with alum and lime, rapid sand filtration, and chlorination to a residual of 1.0 ppm. As contact time in the chemical mixing tank was relatively short, it was decided to add carbon every one-half

hour. Dry carbon was added directly from bags to one of the chemical feed tanks. Little or no difficulty was encountered in producing a palatable water. The water treated at the plant varied from 1 to 3-1/2 million gallons per day depending on whether Green River or Rock Springs pumps or all pumps were in operation. The average use of water by the two communities was approximately 2 mgd.

The water intake from the river was about four miles below toxicant application Station No. 13. All pumps were shut off at 11:00 p.m., September 5, the estimated time at which the toxicant would reach the intake. All pumps remained off and water was used from storage until Green River pumps (1 mgd) were started at 8:00 a.m., September 6. Analysis of raw water at this time indicated a concentration of about 3 ppm of toxicant. Carbon was added at the rate of one-half bag (25 pounds) per one-half hour and was apparently adequate as tests showed no toxicity or odor in the finished water. When Rock Springs pumps were also started (total - 3-1/2 mgd), tests indicated some toxicant was passing through. Carbon was increased to one bag (50 pounds) per one-half hour and continued until the Rock Springs pumps were shut off at midnight. Depending on the toxicant concentration in the raw water and the pumping rate, carbon was continued in estimated necessary amounts for six days until tests showed no toxicant remaining in the raw water. An estimated 1,600 pounds of carbon were used during the first 24 hours, 850 pounds during the second, 500 pounds during the third, 300 pounds during the fourth, and 150 pounds each day during the fifth and sixth. The total amount of carbon used during the operation was approximately 3,500 pounds.

Only twice during the operation was toxicity or odor detected in the finished water at the plant, once as mentioned above when insufficient carbon was used, and again on the third day when carbon was temporarily discontinued

to see if there was enough carbon deposited on the filters or in the rest of the system to remove the toxicant without further addition. As toxicant was detected in the finished water rather rapidly, the addition of carbon was resumed.

During the whole operation, there were no consumer complaints concerning taste or odor. On one occasion when a defective sand filter was used and a slight amount of carbon entered the distribution system, several customers near the plant called to inquire if the fish poison turned the water black.

Dutch John, Utah - The water plant at this site was a package plant with complete treatment and a long retention time between chemical treatment and use. It was decided that batch treatment with carbon every 24 hours would be adequate. Thus, enough carbon was added through a chemical feeder to remove toxicant from a 24-hour water supply, about 300,000 gallons.

The water plant intake was located on the river just below Flaming Gorge Dam, approximately 10 miles below the last toxicant application station (Station 22). The water was pumped from the river into a settling reservoir before arriving at the water plant. As it was not known what type of channelization, etc. may take place in the reservoir, it was decided to compute the amount of carbon needed on the toxicant concentration in the river intake rather than in the plant raw water intake.

The pump from the river was stopped at 2:00 a.m., September 7, and stored water was used for 30 hours or until 8:30 a.m., September 8. When the pumps resumed operation, carbon was added, based on toxicant concentration, in an adequate amount to last for 24 hours. The amount of carbon added was 200 pounds for the first 24 hours, 164 pounds for the second, and 150 pounds

for the third. As it was necessary to discontinue laboratory operations at this time, instructions were given to continue with this amount for several days or until no odor was detectable in the raw water. It was found later that 150 pounds per day were continued for three days and 50 pounds per day were added for an additional week or until September 20. The total amount of carbon used, 1,300 pounds, was probably more than actually needed. While the toxicant concentration reached 2.3 ppm in the river intake, the maximum concentration in the plant raw water was 1.1 ppm. Also, the toxicant probably dissipated before the carbon was discontinued. While carbon in some excess may have been used, this was generally one of the most successful water plant operations throughout the area. As far as could be determined, not a single consumer complaint was received during the whole operation.

Other Plants - The downriver water plants, California Oil Company, and Green River, Utah, had complete water treatment plants and were equipped to add carbon. While these plants were alerted to the toxicant operation, no tastes and odors materialized and it was unnecessary to add carbon. Threshold odor tests were conducted twice daily during the period September 14-22 at the Green River, Utah, water plant. No odors attributable to either the toxicant or dead fish were detected at this plant.

EFFECT ON POLLUTIONAL PARAMETERS

Selected physical, chemical, bacteriological, and biological analyses were conducted on samples from various locations in the river throughout the area treated with toxicant and in the vicinity of several domestic water supplies further downriver. It was not known what effect the toxicant, the resulting dead fish, or the potassium permanganate used for detoxification may have on such conventional pollution measurements as

dissolved oxygen, biochemical oxygen demand, manganese, ammonia, coliforms, or bottom animals. Because of limited personnel available and the long reach of river covered (over 400 miles), it was impossible to study all of the parameters at the many points of interest. Consequently, the data on some of the parameters are confined to one or two key locations.

Physical and Chemical Conditions

Physical and chemical determinations included pH, alkalinity, hardness, conductivity, temperature, dissolved oxygen, biochemical oxygen demand, manganese, and ammonia. The results of these analyses are shown in Table 6. Stream flow data during the major sampling periods, obtained from U. S. Geological Survey records, are shown in Table 7.

Conductivity, pH, Alkalinity, Hardness:

The above characteristics were measured on a limited number of samples throughout the whole reach of the river studied. As may be expected, these characteristics were not significantly affected by the toxicant operation. While there was some increase in all of these characteristics on samples collected several weeks following the toxicant operation (Table 6 - bottom animal stations), this was attributed mainly to decreased river flow. These characteristics also showed a progressive increase from upstream to downstream stations, most likely attributable to increased salts from natural drainage.

The higher pH values at bottom animal Stations 4, 5, and 6 could have resulted partly from the toxicant operation. Following the operation, the river cleared considerably, probably due to the elimination of bottom feeding fish, and a prolific growth of filamentous green algae and stalked diatoms, mostly Gomphonema, was established on the river bottom. This luxuriant vegetation could have increased the utilization of free and fixed

TABLE 6

Physical and Chemical Results

Sample Location	Collected Date	Collected Time	pH	Alk. ppm $CaCO_3$	Hard. ppm $CaCO_3$	Cond. µ mhos	Temp. °C.	DO ppm	BOD ppm	Manganese ppm	Ammonia ppm
Hwy. 189 Bridge at Daniel, Wyo. (Bottom Animal Sta. 1)	7-17-62	1300	8.0	74	104	220	13	8.2	-	-	-
	3-20-63	1430	8.1	144	196	415	0	10.6	-	-	-
Loman Ranch (5 mi. below Toxicant Sta. 1)	9-4-62	1300	8.1	102	174	300	14	-	-	-	-
2 Miles North of LaBarge, Wyo. (Bottom Animal Sta. 2)	8-24-62	1400	8.4	102	122	240	15	9.0	-	-	-
	9-21-62	1230	8.2	124	135	300	16	9.6	-	-	-
	3-20-63	1700	8.1	154	150	340	0	10.6	-	-	-
Names Hill, Wyo. (Below Toxicant Sta. 6)	9-7-62	1020	8.3	136	158	-	-	-	-	-	-
	9-8-62	1120	8.2	132	163	-	13	-	-	-	-
Fontenelle, Wyo. Water Plant Intake from River	9-5-62	1300	8.1	134	174	-	-	-	-	-	-
	9-6-62	1600	8.2	142	190	-	-	-	-	-	-
	9-7-62	1050	8.0	140	180	-	-	-	-	-	-
	9-8-62	1025	8.2	138	175	-	-	-	-	-	-
Finished Water	9-6-62	1630	8.2	138	168	-	-	-	-	-	-
Below Fontenelle Bridge (Bottom Animal Sta. 3)	8-24-62	1130	8.2	112	132	260	15	8.4	-	-	-
	9-21-62	1130	8.3	136	155	340	16	8.4	-	-	-
	3-21-63	930	8.3	156	184	420	0	10.6	-	-	-
Big Island (Toxicant Sta. 11)	9-7-62	1140	8.4	140	222	-	-	-	-	-	-
Stauffer Water Plant Intake from River	9-6-62	1810	8.2	138	200	-	-	-	-	-	-
	9-7-62	1405	8.2	140	210	-	-	-	-	-	-
	9-8-62	905	8.2	138	220	-	-	-	-	-	-
Finished Water	9-6-62	1800	8.2	132	12	-	-	-	-	-	-

TABLE 6
(Continued)

Sample Location	Collected Date	Collected Time	pH	Alk. ppm $CaCO_3$	Hard. ppm $CaCO_3$	Cond. µ mhos	Temp. °C.	DO ppm	BOD ppm	Manganese ppm	Ammonia ppm
1 Mile above Green River, Wyo.	8-24-62	1730	8.2	124	164	440	18	8.6	-	-	-
(Bottom Animal Sta. 4)	9-20-62	1730	8.7	124	200	610	18	10.4	-	-	-
	3-21-63	1100	8.4	170	248	600	0	11.0	-	-	-
Green River, Wyo., Water Plant	9-5-62	1000	8.2	140	210	-	16	8.0	-	-	-
Intake from River	9-7-62	2115	8.2	146	215	-	18	6.6	-	-	-
	9-8-62	815	-	-	-	-	15	7.4	-	-	-
	9-8-62	1030	8.2	142	218	-	15	8.0	-	-	-
	9-8-62	1430	-	-	-	-	16	8.6	-	-	-
Hwy. 530 Bridge at Green River, Wyo.	9-6-62	1630	8.3	136	204	-	-	-	-	-	-
	9-7-62	1535	8.2	140	216	-	-	-	-	-	-
3 Miles below Green River (ICC Park)	8-24-62	1900	8.4	122	170	460	18	8.6	-	-	-
(Bottom Animal Sta. 5)	9-20-62	1630	8.7	126	216	600	19	12.0	-	-	-
	3-21-63	1330	8.4	160	248	660	2	11.6	-	-	-
1 Mile below Toxicant Sta. 18	9-6-62	1300	8.2	140	210	-	-	-	-	-	-
Linwood Bridge	8-25-62	1000	8.4	122	174	380	18	8.0	-	-	-
(Bottom Animal Sta. 6)	9-8-62	1615	8.2	132	230	-	16	-	-	-	-
	9-20-62	1500	8.5	128	204	620	19	8.4	-	-	-
	3-21-63	1500	8.4	172	300	760	8	10.0	-	-	-
Toxicant Sta. 21	9-7-62	1045	8.2	134	252	-	-	-	-	-	-
Toxicant Sta. 22	9-7-62	1115	8.4	144	226	-	-	-	-	-	-

TABLE 6
(Continued)

Sample Location	Collected Date	Collected Time	pH	Alk. ppm $CaCO_3$	Hard. ppm $CaCO_3$	Cond. µ mhos	Temp. °C.	DO ppm	BOD ppm	Manganese ppm	Ammonia ppm
Dutch John Water Plant	9-5-62	Composite[1/]	8.5	-	-	626	-	-	0.85	0.09	-
Intake from River	9-7-62	1400	8.4	134	222	-	-	-	-	-	-
	9-7-62	1700	8.4	140	220	-	-	8.0	-	-	-
	9-7-62	2000	8.4	138	235	-	-	-	-	-	-
	9-7-62	2300	8.4	128	220	-	-	7.0	-	-	-
	9-8-62	800	8.4	132	235	-	16	7.8	-	-	-
	9-8-62	1500	8.3	124	245	-	17	-	-	-	-
	9-8-62	2200	8.4	126	235	-	15	-	-	-	-
	9-10-62	930	-	-	-	-	15	7.4	-	-	-
	9-10-62	1530	-	-	-	-	17	8.8	-	-	-
	9-10-62	Composite[1/]	8.4	-	-	690	-	-	1.1	0.20	-
	9-11-62	800	8.3	144	250	-	15	7.8	-	-	-
Raw from Pond	9-7-62	800	8.4	128	240	-	-	7.4	-	-	-
	9-8-62	1500	8.4	110	225	-	-	-	-	-	-
	9-8-62	2200	8.4	118	235	-	-	-	-	-	-
	9-9-62	1300	8.4	118	245	-	-	-	-	-	-
	9-9-62	2100	8.3	118	225	-	-	-	-	-	-
	9-10-62	1300	8.4	130	-	-	-	-	-	-	-
	9-10-62	2100	8.3	142	240	-	-	-	-	-	-
	9-11-62	830	8.4	130	240	-	-	-	-	-	-
Finished Water	9-7-62	800	8.6	66	180	-	-	7.8	-	-	-
	9-8-62	1500	8.4	108	250	-	-	-	-	-	-
	9-8-62	2200	8.6	66	215	-	-	-	-	-	-
	9-9-62	1300	8.6	60	225	-	-	-	-	-	-
	9-9-62	2100	8.4	60	190	-	-	-	-	-	-
	9-10-62	1300	8.4	62	185	-	-	-	-	-	-
	9-10-62	2100	8.4	70	200	-	-	-	-	-	-
	9-11-62	800	8.4	100	220	-	-	-	-	-	-
	9-17-62	Composite[1/]	-	-	-	685	-	-	1.0	0.20	-
	9-25-62	Composite[1/]	8.4	-	-	822	-	-	1.4	0.00	-

TABLE 6
(Continued)

Sample Location	Collected Date	Collected Time	pH	Alk. ppm $CaCO_3$	Hard. ppm $CaCO_3$	Cond. µ mhos	Temp. °C.	DO ppm	BOD ppm	Manganese ppm	Ammonia ppm
Above Detoxification Station	9-8-62	1400	8.2	128	240	-	-	-	-	-	-
	9-8-62	1800	8.3	128	230	-	-	-	-	-	-
	9-9-62	1330	8.4	124	235	-	-	-	-	-	-
	9-10-62	1300	8.3	144	235	-	-	-	-	-	-
Below Detoxification Station	9-8-62	930	8.4	116	220	-	-	-	-	-	-
	9-8-62	1245	8.4	126	225	-	-	-	-	-	-
	9-8-62	1430	8.3	124	240	-	-	-	-	-	-
	9-8-62	1800	8.3	126	235	-	-	-	-	-	-
	9-9-62	100	8.4	124	250	-	-	-	-	-	-
	9-10-62	1315	8.4	146	230	-	-	-	-	-	-
Dinosaur National Monument (Bottom Animal Sta. 7)	3-22-63	1000	8.4	164	236	750	5	10.6	-	-	-
Hwy. 40 Bridge at Jensen, Utah	9-5-62	Composite[1/]	8.4	-	-	623	-	-	-	0.09	-
	9-10-62	Composite[1/]	8.4	-	-	671	-	-	1.4	0.04	-
	9-17-62	Composite[1/]	-	-	-	714	-	-	1.2	0.05	-
	9-25-62	Composite[1/]	8.2	-	-	822	-	-	2.5	0.80	-
Calif. Oil Co. Infiltration Wells Red Wash, Utah	9-10-62	Composite[1/]	8.0	-	-	718	-	-	1.5	2.00	-
	9-17-62	Composite[1/]	-	-	-	836	-	-	2.0	0.10	-
	9-25-62	Composite[1/]	7.8	-	-	1468	-	-	1.2	0.01	-
2 Miles above Green River, Utah	9-14-62	945	8.5	180	300	922	18	8.6	1.2	.00	.10-.17
	9-14-62	1630	8.1	174	288	858	21	9.0	1.2	-	.00-.05
	9-15-62	915	8.4	172	280	914	19	8.3	1.3	-	.00-.05
	9-15-62	1500	8.4	172	284	902	22	9.0	1.2	-	.00-.05

TABLE 6
(Continued)

Sample Location	Collected Date	Collected Time	pH	Alk. ppm $CaCO_3$	Hard. ppm $CaCO_3$	Cond. µ mhos	Temp. °C.	DO ppm	BOD ppm	Manganese ppm	Ammonia ppm
2 Miles above Green River, Utah (Continued)	9-16-62	930	8.3	178	300	964	19	8.5	1.1	-	.00-.05
	9-17-62	900	8.4	180	324	924	19	8.3	1.1	-	.00-.05
	9-18-62	1000	8.3	184	308	950	20	8.2	0.8	.00	.00-.05
	9-18-62	1615	-	-	-	-	23	8.7	0.9	-	-
	9-19-62	900	8.2	178	308	858	19	8.1	0.9	.00	.17-.24
	9-19-62	1530	-	-	-	-	22	8.4	0.8	-	-
	9-20-62	915	8.7	176	296	933	19	7.8	0.9	-	.10-.17
	9-20-62	1530	-	-	-	-	22	8.7	0.8	-	-
	9-21-62	915	8.1	184	308	933	19	8.0	0.9	-	.24-.34
	9-21-62	1445	-	-	-	-	22	8.7	1.0	-	-
	9-22-62	915	7.7	168	1000	2420	15	1.6 2/	5.3 2/	TR	.24-.34
	9-27-62	p.m.	8.2	192	346	1096	18	8.0	0.5	TR	-
	9-28-62	a.m.	8.1	176	364	1290	16	7.9	0.4	TR	-
	10-11-62	p.m.	8.2	189	399	1323	16	8.2	0.4	> .02	-
	10-12-62	a.m.	8.1	195	390	1218	14	8.6	0.7	TR	-
Green River, Utah, Water Intake	9-14-62	915	8.4	170	288	889	18	8.3	1.5	-	.00-.05
	9-14-62	1600	8.3	172	276	924	22	8.8	1.4	.04	.00-.05
	9-15-62	845	8.4	172	280	828	19	8.2	1.8	-	.00-.05
	9-15-62	1445	8.4	174	280	912	21	8.6	1.1	.04	.00-.05
	9-16-62	915	8.4	174	288	882	19	8.1	1.1	.02	.00-.05
	9-17-62	845	8.5	176	292	903	19	7.9	1.2	.02	.00-.05
	9-18-62	930	8.4	174	288	910	19	7.6	1.4	.00	.00-.05
	9-18-62	1545	-	-	-	-	23	8.6	1.2	.02	-
	9-19-62	845	8.3	176	296	836	19	7.8	1.2	-	.10-.17
	9-19-62	1500	-	-	-	-	22	8.3	1.0	.01	-
	9-20-62	845	8.6	180	292	945	20	7.6	3.1	.00	.17-.24
	9-20-62	1500	-	-	-	-	21	8.5	1.0	.02	-

TABLE 6
(Continued)

Sample Location	Collected Date	Collected Time	pH	Alk. ppm $CaCO_3$	Hard. ppm $CaCO_3$	Cond. µ mhos	Temp. °C.	DO ppm	BOD ppm	Manganese ppm	Ammonia ppm
Green River, Utah Water Intake (Continued)	9-21-62	900	8.5	178	288	910	18	7.8	2.8	.01	.10-.17
	9-21-62	1515	-	-	-	-	21	8.6 2/	1.1 2/	-	-
	9-22-62	900	7.7	162	890	2200	16	1.3 2/	5.8 2/	.10	.34-.42
	9-27-62	p.m.	8.2	184	332	1118	18	7.9	0.4	.00	-
	9-28-62	a.m.	8.2	188	356	1268	17	8.2	0.3	.15	-
	10-11-62	p.m.	8.2	189	384	1260	16	8.1	0.7	.02	-
	10-12-62	a.m.	8.1	195	382	1218	14	8.5	0.7	.02	-
Green River, Utah Finished Water	9-14-62	915	8.0	157	284	865	21	-	-	-	.00-.05
	9-14-62	1600	8.2	156	276	902	24	-	-	-	.00-.05
	9-15-62	845	8.2	158	276	828	21	-	-	-	.00-.05
	9-15-62	1430	8.2	158	272	841	22	-	-	-	.05-.10
	9-16-62	930	8.2	162	280	928	20	-	-	-	.10-.17
	9-17-62	830	8.2	164	304	882	22	-	-	-	.05-.07
	9-18-62	915	8.1	162	300	890	22	-	-	-	.00-.05
	9-19-62	845	8.2	162	292	924	22	-	-	-	.24-.29
	9-20-62	845	8.5	166	300	914	22	-	-	-	.17-.24
	9-21-62	900	8.1	172	300	946	21	-	-	-	.34-.42
	9-22-62	845	7.8	168	304	902	-	-	-	-	.24-.34
	9-27-62	p.m.	8.2	170	360	1096	-	-	-	-	-
	9-28-62	a.m.	8.2	164	364	1290	-	-	-	-	-
	10-12-62	a.m.	8.1	167	386	1239	17	-	-	-	-
5 Miles below Green River, Utah	9-14-62	1015	8.4	167	268	866	21	9.4	1.1	-	.00-.05
	9-14-62	1700	8.3	168	268	902	22	9.1	1.2	-	.00-.05
	9-15-62	945	8.5	168	268	817	20	9.0	1.4	-	.00-.05
	9-15-62	1530	8.5	166	272	871	24	9.3	1.1	-	.05-.10

TABLE 6
(Continued)

Sample Location	Collected Date	Collected Time	pH	Alk. ppm $CaCO_3$	Hard. ppm $CaCO_3$	Cond. µ mhos	Temp. °C.	DO ppm	BOD ppm	Manganese ppm	Ammonia ppm
5 Miles below Green River, Utah (Continued)	9-16-62	1030	8.4	166	280	894	22	8.8	1.2	-	.10-.17
	9-17-62	930	8.5	170	288	819	21	9.0	1.5	-	.00-.05
	9-18-62	1045	8.4	170	288	910	22	9.1	1.3	-	.00-.05
	9-18-62	1700	-	-	-	-	24	9.0	1.2	-	-
	9-19-62	945	8.4	172	284	902	21	8.7	1.0	-	.10-.17
	9-19-62	1600	-	-	-	-	22	7.9	2.1	-	-
	9-20-62	1600	-	-	-	-	22	9.1	1.0	-	-
	9-21-62	1545	-	-	-	-	21	7.2	1.0	-	-
	10-11-62	p.m.	8.4	185	398	1386	16	8.3	1.1	-	-
	10-12-62	a.m.	8.1	195	390	1218	-	8.4	0.5	-	-

1/Analyses by Utah State Health Department
2/River very turbid - DO and BOD analyses affected

TABLE 7

Green River Flow Data[1/]
Daily Discharge in Cubic Feet per Second

Date	Location					
1962	Daniel, Wyoming	Fontenelle, Wyoming	Green River, Wyoming	Linwood, Utah	Jensen, Utah	Green River, Utah
7/17	1,190	4,030	4,320	5,500	6,620	7,410
8/24	581	1,130	1,130	1,200	1,780	2,170
8/25	518	1,110	1,110	1,160	1,730	2,110
9/4	230	720	798	844	1,250	1,680
9/5	219	680	774	814	1,220	1,640
9/6	216	650	742	790	1,200	1,600
9/7	202	630	703	766	1,160	1,540
9/8	202	602	675	732	1,110	1,500
9/9	205	602	640	705	1,060	1,450
9/10	205	602	626	685	1,020	1,430
9/14	190	593	598	675	870	1,320
9/15	184	584	577	670	870	1,290
9/16	176	575	570	650	863	1,270
9/17	170	566	563	642	863	1,250
9/18	170	539	556	642	828	1,200
9/19	162	523	549	637	814	1,200
9/20	165	516	549	632	807	1,220
9/21	181	575	556	675	849	2,510
9/22	233	620	577	738	870	2,950
9/25	254	620	626	685	828	1,470
9/27	233	620	619	685	863	1,540
9/28	226	611	612	680	863	3,190

1/ Data from U. S. Geological Survey Flow Records.

carbon dioxide from the river water resulting in an increased pH value. This hypothesis is further supported by the increased dissolved oxygen values at these same stations, probably due to increased photosynthetic activity.

Dissolved Oxygen, Biochemical Oxygen Demand:

It was thought possible that the large tonnage of decaying fish resulting from the toxicant operation may have some effect on dissolved oxygen or biochemical oxygen demand. DO determinations were made at bottom animal stations before and several weeks after the toxicant operation. During the operation, DO analyses were made at Green River, Wyoming, Dutch John, Utah, and Green River, Utah. BOD determinations were made by the Utah State Health Department at Dutch John, Jensen, and Red Wash, Utah, and by the Colorado River Basin Project's mobile laboratory at Green River, Utah.

From the DO and BOD results (Table 6), it appears that the toxicant operation had no major effect on these parameters. From the values obtained at Green River, Wyoming, and Dutch John, Utah, it appears that there was a slight decrease in oxygen (1 - 2 ppm) for a day or two immediately following the arrival of the toxicant which may have been caused by the utilization of oxygen by the methylated naphthalene carrier. Values, however, rapidly rose to normal and, in fact, several weeks later were above pre-operational levels, probably due to increased photosynthetic activity as previously mentioned. The two very low values at Green River, Utah, on September 22 were believed to be due to difficulty in analysis of the extremely turbid water samples following a heavy rainfall. The toxicant was scheduled to arrive in this vicinity on September 18 or 19, at which time values were only slightly below normal.

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BOD results were generally low (0.8 - 1.8) at all sampling stations and showed no significant changes during the sampling periods. The few high values (5.3 - 5.8) at Green River, Utah, were believed to be due to difficulty in analysis of the highly turbid samples following the September 21 rainfall. Several slightly higher than normal values (2.1 - 3.1) were found on September 19, 20, and 21 which may reflect some minor effect from the upstream toxicant operations. It could be concluded from these results that the toxicant operation or the resulting dead fish had no significant effect on DO or BOD values.

Manganese:

Approximately 17,600 pounds of potassium permanganate were distributed into the river at the detoxification station over a 3-1/2 day period. It was suspected that some of the manganese would remain in solution and could be detected at water plants downstream. The Utah State Health Department conducted manganese analyses at Dutch John, Jensen, and Red Wash, Utah, and Colorado River Basin Project personnel conducted analyses at Green River, Utah, before and after suspected arrival of the material.

The results of manganese analyses (Table 6) indicate no definite pattern or trend of increased manganese in downriver water supplies. The highest result (2.0 ppm) was obtained at Red Wash, Utah, approximately 85 miles below the detox station on September 10 before the material could possibly have arrived at this point. Another high value (0.8 ppm) at Jensen on September 25 may have resulted from the detoxification operation; however, this increase should also have shown up in the prior sample on September 17. Heavy rainfalls occurred between these sampling periods which may have scoured the river bottom and returned some of the precipitated

manganese into solution. Slightly higher manganese values were also found at Green River, Utah, 260 miles below the detox station following the heavy rainfalls. Other values before and after the predicted arrival of the material were in a similar range of 0.0 to 0.4 ppm and indicated no increase due to the detoxification operations.

It may be concluded from these data that manganese did not remain in solution to cause an immediate increase in downstream water supplies at the predicted time of arrival. Later, however, heavy rains may have caused precipitated manganese to re-enter solution and increase downstream concentrations.

Ammonia:

It was suspected that decaying fish resulting from the toxicant operation may increase ammonia concentrations in downstream waters. Ammonia analyses, however, were conducted only in the area of Green River, Utah.

Results of analyses (Table 6) indicate an increase in ammonia concentrations at the predicted time of arrival of effects of the toxicant operation. On September 19, 20, and 21 ammonia concentrations increased to levels (.10 - .42 ppm) higher than previously (.00 - .05 ppm). This was the only chemical measurement that showed a definite increase at downstream stations at the predicted time of toxicant effect that was not associated with the period of heavy rainfall and high water conditions.

Bacteriological Conditions

During and following the toxicant operation, bacteriological studies were conducted on the Green River within and below the area of toxicant application. Major purposes were to obtain background information on this section of the river, to determine if the toxicant or resulting dead fish had any effect on coliform levels, and to ascertain that finished waters

from the water plants treating river water were of acceptable bacterial quality.

MF coliform determinations were made on raw and finished water from September 5 through September 8 in facilities provided at the Green River, Wyoming, water treatment plant. A few samples were collected in upstream areas near LaBarge, Wyoming, and at the Stauffer and Intermountain Chemical Company plants. At Green River, samples were collected above the city, at the water treatment plant, and at three points below the city. Several samples were procured from Dutch John, Utah.

The Utah State Health Department conducted MPN coliform determinations on river samples from Dutch John, Jensen, and Red Wash, Utah. Samples were collected every two hours for a 12-hour period on September 5, 10, 17, and 25 and transported to its laboratory in Salt Lake City for analysis.

The Colorado River Basin Project's mobile laboratory was set up at the Green River, Utah, water plant approximately 260 miles below the detoxification station. It was estimated from flow-rate data that any effects of the toxicant operation would reach this area about September 18. MF coliform determinations were made on river waters from several points above and below Green River and on raw and finished water from the water plant. Tests were conducted from September 14 through September 21, when heavy rainfall and flood conditions halted operations. Two later sets of samples were collected and transported to Salt Lake City for analysis. Some additional bacteriological tests were conducted on these samples.

Table 8 lists the MF coliform counts obtained at various sampling points as the toxicant progressed downstream. Samples taken before the toxicant was scheduled to exert an effect served as controls. The coliform

TABLE 8

Bacteriological Results

River Samples
Coliform MF Counts

Sample Location	Date	Time	Temp. °C.	MF Coliforms per 100 ml.
About 1/2 Mile above Names Hill Cafe, LaBarge, Wyoming	9-8-62	1120	13.0	36
From Bridge below Fontenelle Camp, Wyoming	9-6-62	1600	17.0	120
	9-8-62	1025	13.3	9
From Bridge at Stauffer Chemical Company, Wyoming	9-6-62	1800	17.0	28
	9-8-62	0925	12.7	6
From Hwy. 30 Bridge about 5 Miles above Green River, Wyoming	9-5-62[1/]	1630	17.0	13
	9-6-62	0900	17.0	< 2.9
		1615	18.5	6
	9-7-62	1120	17.0	4
		1630	18.0	< 2.9
	9-8-62	0915	13.5	12
Intake, Water Treatment Plant, Green River, Wyoming	9-5-62	1530	17.5	< 6.2
Raw Water, Water Treatment Plant, Green River, Wyoming	9-5-62[1/]	1500	17.5	13
		2230	18.0	19
	9-6-62	1015	18.0	21
		2150	18.0	3
	9-7-62	1630	18.0	34
		2300	18.0	9
	9-8-62	1715	15.0	3
Treated Water before Chlorination, Water Treatment Plant, Green River, Wyoming	9-5-62[1/]	1500	18.0	< 6.2
		2230	18.5	< 2.5
	9-6-62	1015	18.5	15
From Hwy. 530 Bridge, Green River, Wyoming	9-6-62	1000	17.0	2,000
	9-7-62	1145	18.0	3,600
	9-8-62	0935	14.0	200
Opposite Entry of Bitter Creek (about 1 Mile below Hwy. 530 Bridge)	9-7-62	1230	17.5	39,000
	9-8-62	1000	14.0	29,000

TABLE 8
(Continued)

Sample Location	Date	Time	Temp °C.	MF Coliforms per 100 ml.
From ICC Park about 4 Miles below Green River, Wyoming	9-5-62[1/]	1815	17.5	14,000
	9-6-62	0930	17.0	17,000
		1645	18.0	31,000
	9-7-62	1150	18.0	7,100
		1650	18.0	22,000
	9-8-62	0945	14.0	16,000
From Hwy. 530 Bridge 5 Miles below Linwood, Utah	9-7-62	1730	17.5	40
River Intake, Water Treatment Plant, Dutch John, Utah	9-7-62	1330	17.0	8
Water Retention Pond, Dutch John, Utah	9-7-62	1820	18.0	16
7 Miles above Hwy. 50-6 Bridge, Green River, Utah	10-11-62	1500	16.5	1,500
	10-12-62	0825	14.3	1,000
About 2 Miles above Hwy. 50 Bridge, Green River, Utah	9-14-62[1/]	0945	18.0	260
		1630	21.0	80
	9-15-62[1/]	0915	19.0	38
		1500	22.0	15
	9-16-62[1/]	0930	20.0	20
		1630	23.0	43
	9-17-62[1/]	0900	19.0	46
		1645	23.0	36
	9-18-62[1/]	1000	20.0	210
		1615	23.0	46
	9-19-62	0900	20.0	66
		1530	22.0	30
	9-20-62	0915	20.0	66
		1530	22.0	26
	9-21-62	0915	19.0	130
		1445	22.0	230
	9-27-62	1600	18.0	1,800
	9-28-62	0830	16.0	1,500
	10-11-62	1605	16.5	700
	10-12-62	0845	14.4	1,100

TABLE 8
(Continued)

Sample Location	Date	Time	Temp. °C.	MF Coliforms per 100 ml.
From Hwy. 50-6 Bridge, Green River, Utah	10-11-62	1800	16.0	1,600
	10-12-62	0730	13.2	800
Intake, Water Treatment Plant, Green River, Utah	9-14-62 1/	0915	18.0	240
		1600	22.0	110
	9-15-62 1/	0845	19.0	80
		1445	21.0	60
	9-16-62 1/	0915	20.0	30
		1600	22.0	83
	9-17-62 1/	0845	19.0	120
		1615	22.0	40
	9-18-62 1/	0930	19.0	110
		1545	23.0	50
	9-19-62	0845	19.0	150
		1500	22.0	67
	9-20-62	0845	20.0	120
		1500	21.0	450
	9-21-62	0900	19.0	310
		1515	21.0	430
	9-27-62	1630	18.0	2,400
	9-28-62	0845	17.0	2,300
	10-11-62	1730	16.0	2,100
	10-12-62	0955	14.0	1,400
About 5 Miles below Green River, Utah	9-14-62 1/	1015	21.0	100
		1700	22.0	40
	9-15-62 1/	0945	20.0	400
		1530	24.0	110
	9-16-62 1/	1030	22.0	180
		1700	24.0	380
	9-17-62 1/	0930	21.0	820
		1715	23.0	180
	9-18-62 1/	1045	22.0	760
		1700	24.0	160
	9-19-62	0945	21.0	860
		1600	22.0	600
	9-20-62	1600	22.0	220
	9-21-62	1545	21.0	2/
	10-11-62	1650	15.3	1,700
	10-12-62	0925		2,000

1/ Before expected effect of fish toxicant application
2/ Excessive turbidity - could not analyze

levels were low and of little significance above Green River, Wyoming, and at the water supply intake. Much higher counts resulted at sampling points below the city which reflect the entrance of sewage from Green River, Wyoming, and sewage from Rock Springs, Wyoming, which enters the river via Bitter Creek approximately one mile below Green River. Average coliform counts at several points exceeded the 5,000 coliforms per 100 ml. generally accepted as satisfactory raw water quality. Samples from the Green River, Utah, area produced no significant coliform counts until a heavy rainfall on September 20 resulted in a large amount of runoff and highly turbid conditions in the river.

There was no evidence that the toxicant operations resulted in a change in coliform levels in any sections of the river. None of the finished water samples (Table 9) showed any coliform count except one sample from Green River, Utah, on September 15 and no coliforms were found there in subsequent samples.

MPN results obtained by the Utah State Health Department are shown in Table 10. While a few individual samples produced high coliform counts, there was no pattern to indicate that the toxicant operation had any effect on increasing or decreasing MPN coliform counts.

Because of the abrupt increase in MF coliform counts at Green River, Utah, following heavy rainfall and runoff, confirmed coliform MPN, fecal coliform MPN, and enterococcus MPN tests were performed on later samples from this area. The enterococcus presumptive test used was azide dextrose broth; all positive tubes were confirmed in ethyl violet azide broth. Table 11 demonstrates that MF coliforms were considerably higher following the runoff, MPN coliforms were above 5,000 per 100 ml., and significant

TABLE 9

Bacteriological Results

Finished Water Samples
Coliform MF Counts

Sample	Location	Date	Time	Temp. °C.	MF Coliforms per 100 ml.
1	Fontenelle Camp, Wyoming	9-6-62	1600	-	< 1.0
		9-8-62	1045	15.3	< 0.5
2	Stauffer Chemical Company, Wyoming	9-6-62	1800	-	< 1.0
		9-8-62	0905	21.3	< 0.5
3	Intermountain Chemical Corp., Westvaco, Wyoming	9-7-62	1030	-	< 1.0
4	Green River, Wyoming	9-5-62 1/	2235	18.5	< 1.0
		9-6-62	2150	18.5	< 1.0
		9-7-62	1710	18.0	< 1.0
			2300	18.5	< 1.0
		9-8-62	1715	16.0	< 1.0
5	Green River, Utah	9-14-62	0915	21.0	< 0.5
		9-15-62	1430	22.0	4
		9-16-62	0930	20.0	< 0.6
		9-17-62	1615	23.0	< 1.0
		9-18-62	0915	22.0	< 0.5
		9-19-62	1500	24.0	< 0.5
		9-20-62	0845	22.0	< 0.5
		9-21-62	1515	22.0	< 0.5
		9-27-62	1700	-	< 0.6
		9-28-62	0900	-	< 0.6
		10-12-62	1005	17.0	< 1.0

1/ Before effect of fish toxicant application

TABLE 10

Bacteriological Results

River Samples
Coliform MPN Counts[1/]

Sample Location	Date	Time	MPN per 100 ml.	Date	Time	MPN per 100 ml.
River Intake, Water Treatment Plant, Dutch John, Utah	9-5-62[2/]	1100	39	9-17-62	800	43
		1300	4		950	23
		1500	23		1200	9
		1700	93		1400	9
		1900	23		1600	43
		2100	9		1800	20
	9-10-62	700	930		2000	93
		900	430		2200	93
		1100	430	9-25-62	800	23
		1300	430		1000	23
		1500	430		1200	43
		1700	240		1400	23
					1600	9
Green River at Jensen, Utah, Hwy. 40 Bridge	9-5-62[2/]	600	150	9-17-62	600	2,300
		800	93		800	9,300
		1000	230		1000	43
		1205	7,500		1200	93
		1400	930		1400	930
		1600	43		1600	23
	9-10-62[2/]	600	43,000	9-25-62	600	430
		800	43		800	430
		1000	23		1000	240
		1200	240		1200	240
		1400	23		1400	430
		1600	15		1600	750
California Oil Co. in Filtration Wells at Red Wash, Utah	9-10-62[2/]	620	93	9-25-62	620	2,300
		1020	2,300		820	2,300
		1220	2		1025	240
		1420	4		1215	23
		1615	2		220	930
	9-17-62	615	2,300		415	93
		820	43,000			
		1020	3			
		1220	43			
		1420	43			

1/ Analyses by the Utah State Health Department
2/ Before expected effect of fish toxicant application

TABLE 11

Results of Four Bacterial Tests from
Green River, Utah, Stations after Heavy Runoff

Date	Time	Temp. °C.	Coliforms per 100 ml. MF Count	Confirmed Coliform MPN	Fecal Coliform MPN	Confirmed Enterococcus MPN
7 Miles above Hwy. 50-6 Bridge, Green River, Utah						
10-11-62	1500	16.5	1,500	4,900	17	2,210
10-12-62	0825	14.3	1,000	13,000	27	490
Mean		15.4	1,250	8,950	22	1,350
2 Miles above Hwy. 50-6 Bridge, Green River, Utah						
9-27-62	1600	18.0	1,800	10,900	490	13,000
9-28-62	0830	16.0	1,500	7,900	330	4,900
10-11-62	1605	16.5	700	4,900	110	1,300
10-12-62	0845	14.4	1,100	1,720	330	490
Mean		16.2	1,300	6,360	320	4,750
From Hwy. 50-6 Bridge, Green River, Utah						
10-11-62	1800	16.0	1,600	13,000	110	790
10-12-62	0730	13.2	800	2,210	230	1,410
Mean		14.6	1,200	7,600	170	1,100
Intake, Water Treatment Plant, Green River, Utah						
9-27-62	1630	18.0	2,400	7,900	230	2,200
9-28-62	0845	17.0	2,300	14,100	1,300	500
10-11-62	1730	16.0	2,100	7,900	110	1,090
10-12-62	0955	14.0	1,400	4,600	20	1,090
Mean		16.3	2,100	8,600	420	1,220
About 5 Miles below Hwy. 50-6 Bridge, Green River, Utah						
10-11-62	1650	15.3	1,700	4,900	230	1,410
10-12-62	0925	14.8	2,000	2,780	20	790
Mean		15.0	1,850	3,840	130	1,100

numbers of fecal coliforms and enterococci were present in these samples, even at a point well above any influence from the town of Green River.

In summary, the bacteriological data gathered during the fish toxicant operation provide background counts on the Green River and show a high coliform level below Green River, Wyoming. This condition would be undesirable if it still exists when Flaming Gorge Dam is completed and the reservoir used for recreational purposes. There is no evidence from the studies which shows any effect of the fish toxicant or dead fish on the coliform population in the river. Finished water from water treatment plants in the area was of acceptable bacterial quality.

Biological Conditions

Bottom animal and plankton samples were collected at selected stations throughout the area of toxicant application. The location of biological sampling stations is shown in Figures 1 and 2 and described in Table 12. Certain physical and chemical conditions (Table 6) were ascertained at the same time and location that biological samples were collected.

Bottom Animals:

While it was reasonably certain that all fish would be eliminated throughout the area of toxicant application, information was desired as to the fate of animals such as insect larvae, worms, mollusks, etc. living on the bottom of the river and serving as a major source of fish food. As bottom animal samples also serve as a good indicator of pollutional conditions, information was also desired as to the rate of recovery of bottom animal populations if reduced or eliminated. Riffle samples were thus taken at sampling stations prior to application of the toxicant severa weeks after the operation and again about six months later to determine extent of recovery.

TABLE 12

Biological Sampling Stations

Station Number	Mileage Index	Location
①	Gr 660	Near Daniel, Wyoming - Hwy. 189 Bridge
②	Gr 598	2 Miles North of LaBarge, Wyoming
③	Gr 578	Hwy. Bridge Just below Fontenelle, Wyoming
④	Gr 505	1 Mile above Green River, Wyoming
⑤	Gr 501	ICC Park - 3 Miles below Green River, Wyoming
⑥	Gr 430	Linwood, Utah - Bridge on Hwy. to Dutch John, Utah
⑦	Gr 310	Dinosaur National Monument - Camp Grounds

Bottom animal samples taken prior to the application of toxicant (Table 13) showed very good populations of a variety (16 - 22 Genera) of clean-water animals at all stations with mayfly nymphs and caddisfly larvae very abundant. Numbers of animals ranged from 183 to 816 per square foot and weights from 0.61 to 4.09 grams per square foot. Two weeks following the toxicant operation, samples taken in the treated area showed a very drastic reduction in bottom animals at all stations. Numbers remaining ranged from 1 to 4 per square foot. Mayfly and stonefly nymphs and caddisfly larvae were practically eliminated. The population remaining consisted of a few midge and beetle larvae and several large dragonfly nymphs.

Samples collected in March 1963, about six months after the toxicant operation, showed little improvement in bottom animal population (Table 13). A few midges were beginning to repopulate the river in the vicinity of Green River, Wyoming (Stations 4 and 5). A sample could not be collected at Station 6 because of backwater from Flaming Gorge Dam. A sample taken at Daniel (Station 1), above the toxicant treated area, however, showed an excellent bottom fauna. A sample collected in Dinosaur National Monument (Station 7), well below the treated area, also showed a good bottom fauna population which would indicate little, if any, effect of the toxicant in this lower section of the river.

It was expected that drift of bottom animals from upstream areas would cause a fairly rapid repopulation of the river in the treated area. The river, however, remained quite low and was ice-covered until shortly before the samples were taken. As there was little opportunity for drift and little winter reproduction, the poor condition may be expected. The

TABLE 13

Numbers of Bottom Animals
Before and After Toxicant Application

Kind of Animal	Station ① Daniel, Wyoming		Station ② LaBarge, Wyoming		
Date:	7-17-62[1/]	3-20-63	8-24-62[1/]	9-21-62	3-20-63
Size Sample:	1 sq.ft.	3 sq.ft.	3 sq.ft.	3 sq.ft.	3 sq.ft.
Ephemeroptera (Mayflies)	103	240	185		
Anisoptera (Dragonflies)					
Plecoptera (Stone Flies)	3	51	8		
Hemiptera (Water Bugs)			3		
Megaloptera (Dobson Flies)					
Trichoptera (Caddisflies)	141	75	250		
Lepidoptera (Aquatic Moths)					
Coleoptera (Water Beetles)	2		3	6	
Diptera (True Flies)	68	440	174	7	4
Oligochaeta (Earthworms)	32	30	1		
Hirudinea (Leeches)		1			
Gastropoda (Snails)	1	9	1		6
Total Number	350	846	625	13	10
Weight (grams)	1.16	1.95	2.51	0.05	0.20
No. of Genera	16	21	21	3	4
No. per Square Foot	350	282	208	4	3
Wt. per Square Foot	1.16	0.65	0.84	0.02	0.07

TABLE 13
(Continued)

Kind of Animal	Station ③ Fontenelle, Wyoming			Station ④ Above Green River, Wyoming		
Date:	8-24-62[1/]	9-21-62	3-20-63	8-24-62[1/]	9-20-62	3-21-63
Size Sample:	3 sq.ft.	3 sq.ft.	3 sq.ft.	3 sq.ft.	2 sq.ft.	3 sq.ft
Ephemeroptera (Mayflies)	276			447		
Anisoptera (Dragonflies)	2	1				
Plecoptera (Stone Flies)	6			10		
Hemiptera (Water Bugs)						1
Megaloptera (Dobson Flies)						
Trichoptera (Caddisflies)	485			145	1	
Lepidoptera (Aquatic Moths)	1					
Coleoptera (Water Beetles)	6	3		1		
Diptera (True Flies)	41			600		40
Oligochaeta (Earthworms)	2			5		
Hirudinea (Leeches)						
Gastropoda (Snails)	14		5	6		
Total Number	833	4	5	1,214	1	41
Weight (grams)	5.20	0.38	0.15	2.13	0.03	0.06
No. of Genera	20	2	2	20	1	6
No. per Square Foot	278	1	2	405	1	14
Wt. per Square Foot	1.73	0.13	0.05	0.71	0.03	0.02

TABLE 13
(Continued)

Kind of Animal	Station (5) Below Green River, Wyoming			Station (6) Linwood Bridge, Utah		Dinosaur (7) Monument, Utah
Date:	8-24-62 1/	9-20-62	3-21-63	8-25-62 1/	9-20-62	3-22-63
Size Sample:	3 sq.ft.	2 sq.ft.	3 sq.ft.	3 sq.ft.	2 sq.ft.	3 sq.ft.
Ephemeroptera (Mayflies)	484			2,089	2	321
Anisoptera (Dragonflies)	2	1		6	1	
Plecoptera (Stone Flies)	6		1	5		13
Hemiptera (Water Bugs)						
Megaloptera (Dobson Flies)						1
Trichoptera (Caddisflies)	15			230	1	72
Lepidoptera (Aquatic Moths)						
Coleoptera (Water Beetles)					2	16
Diptera (True Flies)	36		32	113		788
Oligochaeta (Earthworms)	4		3	5	5	3
Hirudinea (Leeches)						
Gastropoda (Snails)	1					
Total Number	548	1	36	2,448	11	1,214
Weight (grams)	1.84	0.12	0.09	12.28	0.02	2.86
No. of Genera	22	1	4	17	6	20
No. per Square Foot	183	1	12	816	4	405
Wt. per Square Foot	0.61	0.12	0.03	4.09	0.01	0.95

1/ Before toxicant application

bottom fauna population should improve greatly following the spring runoff and summer reproduction periods. No references could be found pertaining to length of time required for recovery of bottom animals following a toxicant operation of this kind.[1/] However, in a large eastern river, from which bottom fauna was eliminated by pollution from toxic industrial wastes, almost complete recovery of bottom animals was apparent about 12 to 15 months following elimination of the pollution source (10).

Plankton:

It was expected that most zooplankton organisms would probably be killed by the toxicant but it should have little, if any, toxic effect on phytoplankton. However, the elimination of animal life which normally feeds on vegetation plus the release of nutrients from the decaying animal life could greatly increase production of aquatic plant life. Consequently, one-gallon water samples were collected for plankton analyses at biological stations before and again two weeks after the toxicant operation. The numbers and types of plankters found are shown in Table 14.

Prior to the toxicant operation, the phytoplankton population consisted of moderate numbers of photoplankton, mostly the diatoms, Navicula, Amphora and Cocconeis, and lesser numbers of green algal forms, mostly Scenedesmus, Cosmarium and Closterium. The zooplankton population was sparse, but with a few protozoans, rotifers, crustaceans, and nematodes present at most stations.

1/ Since this report was written, additional information on bottom animals has been obtained by personal communication with Dr. Donald Franklin, Leader, U.S. Fish and Wildlife Service Fisheries Cooperative Unit, Logan, Utah; Mr. Don Adriano, Chief of Fisheries, Utah Fish and Game Dept., Salt Lake City, Utah; and Mr. Fred Eiserman, Chief, Fish Management, Wyoming Game and Fish Dept. Their information indicates that bottom animal populations had shown a good recovery by the winter of 1963-1964. Populations of most organisms were equivalent to pre-treatment levels although some species differences were noted. Reports on some of these studies should be available within another year. An excellent fishery for rainbow trout has been established in Flaming Gorge Reservoir and in the Green River above and below the impoundment. Many thousands of fishermen are now using this area and sport fishing is considered excellent. Trout which were stocked as fingerlings in early 1963 are reported as ranging up to 16 inches and are in excellent condition.

TABLE 14

Numbers and Kinds of Plankters
Before and After Toxicant Application

Sample Location	Collected Date	Collected Time	Phytoplankton - Organisms per Milliliter Diatoms	Greens	Bluegreens	Flagellates	Total	Zooplankton - Organisms per Liter Protozoa	Rotifers	Crustacea	Nematodes	Total
① Daniel, Wyoming, Hwy. 189 Bridge	7-16-62[1/]	930	147	9	7	5	168	40	10	0	20	70
② LaBarge, Wyoming	8-24-62[1/]	1400	212	24	5	5	246	200	10	0	10	220
	9-21-62	1230	673	411	23	11	1,118	500	0	0	0	500
③ Fontenelle, Wyoming	8-24-62[1/]	1130	763	94	2	9	868	180	60	0	60	300
	9-21-62	1130	371	37	5	2	415	2,235	0	0	0	2,235
④ Above Green River, Wyoming	8-24-62[1/]	1730	1,143	167	2	0	1,312	40	0	20	20	80
	9-20-62	1700	537	109	11	0	657	1,840	0	0	10	1,850
⑤ Below Green River, Wyoming	8-24-62[1/]	1900	1,053	190	11	2	1,256	10	20	20	20	70
	9-20-62	1630	491	173	3	1	668	2,170	5	0	0	2,175
⑥ Linwood, Utah	8-25-62[1/]	900	305	103	5	0	413	20	40	0	0	60
	9-20-62	1500	452	202	15	4	673	395	5	5	0	405

1/ Before toxicant application.

Surprisingly, the phytoplankton population was not greatly different in samples taken two weeks after the toxicant operation. While visual observation showed a very heavy growth of the filamentous green algae, Cladophora, and the stalked diatom, Gomphonema, on the bottom of the river, these forms were not at all abundant in the water samples analyzed. The diatom, Synedra, increased in numbers to become the dominant form but other phytoplankton forms remained about the same as in the "before" samples.

The greatest change in the plankton population was in one group of the zooplankters, the protozoans. These animals increased markedly (from 10 to 200 times) at all of the sampling stations, while other zooplankters decreased and were absent at most of the stations.

Observations were made in March, six months after the toxicant application, and following the breakup of the winter ice cover. Most of the filamentous algae had disappeared from the bottom of the river. The attached diatom growth, mostly Gomphonema, on the river bottom was beginning to decay and many small masses and cottony filaments were floating or suspended in the river waters. Probably the decreased light during the winter ice cover had been the major cause of this condition.

Reports from operators indicate that some difficulty was encountered in the Green River, Wyoming, water treatment plant during February and early March, coinciding with the breakup of the ice cover. The length of filter runs was considerably shortened, tastes and odors were produced which required further use of carbon, and it was difficult to obtain a chlorine residual. These effects could be attributed to the decay of the algae and diatom masses with a resulting increase in suspended material and dissolved organics. As this condition had not been encountered in previous years, it could possibly be attributed to the increased aquatic vegetation growth following the toxicant operation.

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